Atlas 1.1 Implementation Guide:

Moving from Theory into Practice

SERC-2018-TR-101-B

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I would like to personally thank the many individuals at the organizations highlighted in this document for their interest in and support of the Helix team and the *Atlas* work. Though those who have presented in public are mentioned, there are many individuals who supported site visits, coordinated with the team, and openly shared information about their organizations. We are extremely grateful to each of them.

I would also like to personally thank the current Helix team, who have helped tremendously to mature not only the project, but my own thinking and views on it. Pam, Ralph, Sergio, Megan, Matthew, and Dinesh, please accept my gratitude for your hard work and dedication.

Nicole AC Hutchison

Nicole AC Hutchison
Helix Principal Investigator

Executive Summary

Atlas *1.1: The Theory of Effective Systems Engineers*, describes the common roles, positions, patterns, skills, and characteristics of systems engineers, the common values they provide, and the organizational context that could support or inhibit their effectiveness.

Whenever *Atlas* is presented, there are many questions about how to take the theory and apply it in practice. As the Helix team has continued to collect data and has worked with and received feedback from organizations that are using and reviewing *Atlas* as a mechanism to improve their systems engineering workforce development, the team has captured approaches that may facilitate and potential pitfalls that may inhibit these improvements. This document provides attributed examples from the organizations that have publicly shared insights on their use of *Atlas*, as well as other lessons learned the team has gathered over the five years of the project.

This document contains:

- An overview of *Atlas* 1.1, for reference
- Examples of organizations which have utilized *Atlas*
- Detailed guidance for individuals to help them use *Atlas* and
- Detailed guidance for organizations to support their use of *Atlas*.

Individuals can use this guide to understand and assess their own knowledge, skills, and abilities; understand and analyze their own career paths; and link the two to develop plans and paths for growth. Organizations will be able to clear and consistent definitions for systems engineering and the value that systems engineer provide; clear and consistent expectations on the roles systems engineers play within the organization; clear and consistent expectations on the knowledge, skills, abilities, behaviors, and cognitions of systems engineers; and career path recommendations and supporting initiatives that enable the growth and development of the systems engineering workforce.

By using *Atlas*, the Helix team believes that organizations can better provide their systems engineers with the information and tools needed to grow and develop into an effective workforce. With this information, the Helix team believes that any individual or organization can implement *Atlas* as appropriated for themselves and without specific support from the team. However, if you have additional questions on implementation or if you would like assistance on implementing *Atlas* in your organization, please contact the Helix team at helix@stevens.edu.

1 Introduction and Purpose

In December 2016, the Helix team released "*Atlas* 1.0: The Theory of Effective Systems Engineers." It described the common roles, positions, patterns, skills, and characteristics of systems engineers, the common values they provide, and the organizational context that could support or inhibit their effectiveness. This has been updated through the Team's work in 2017, and *Atlas* 1.1 (SERC-2018-TR-101-A) was released concurrently with this document. (2018)

Whenever *Atlas* is presented, there are many questions about how to take the theory and apply it in practice. As the Helix team has continued to collect data and has worked with and received feedback from organizations that are using and reviewing *Atlas* as a mechanism to improve their systems engineering workforce development, the team has captured approaches that may facilitate and potential pitfalls that may inhibit these improvements. This document provides attributed examples from the organizations that have publicly shared insights on their use of *Atlas*, as well as other lessons learned the team has gathered over the five years of the project. Note that in Helix, the team has strict protocols in place to protect the anonymity of participating organizations and individuals; this is why only organizations that have publicly shared their stories are named here.

This document is one of a suite which were published simultaneously reflecting the team's work in 2017:

- ***Atlas* 1.1** – This is an incremental evolution of *Atlas* that reflects feedback from the community, additional analysis, and maturation of the team's thinking in 2017. (SERC-2018-TR-101-A)

- ***Atlas Career Path Guidebook*** – This document provides analyses of the Helix dataset, providing common patterns in systems engineers' careers. The Guidebook also provides some insights on questions commonly asked of the Helix team around career paths and the team's responses. Finally, additional work on linking proficiencies to career paths has been completed and is reflected in the guide. (SERC-2018-TR-101-C)

- ***2017 Helix Technical Report*** – This document provides an overview of the work completed in 2017 along with the team's vision and planning for future Helix work. It references, rather than repeats, the findings of the other documents. In addition, it captures the detailed methodologies utilized on the Helix project. (SERC-2018-TR-101)

The relationships between these documents are illustrated in Figure 1, below.

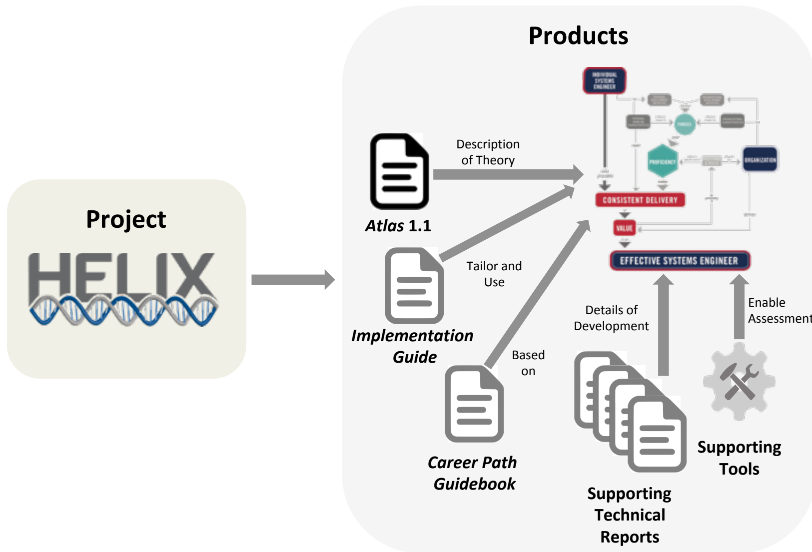


Figure 1. Relationship between Helix, Atlas, and Additional Documents

1.1 Users and Use Cases

There are two primary ways in which *Atlas* can be used – to provide insight and guidance to individuals and to inform organizational-level efforts. Guidance on how to use various aspects of *Atlas* is provided throughout the various sections of this document. This section pulls this together, describing at a high level the major expected uses for *Atlas*. Several organizations have, to varying degrees, tried all of them. Figure 2 shows individual uses.

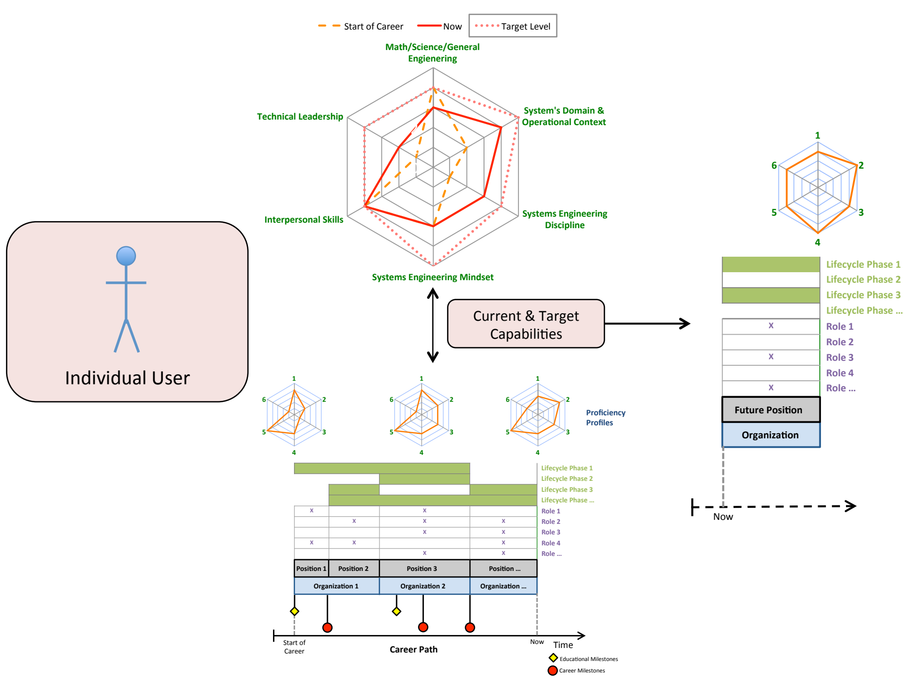


Figure 2. Expected Uses for an Individual User

As shown in Figure 2, with the help of this *Guide* an individual is expected to be able to:

1. **Use Proficiency Self-Assessment to identify current proficiency levels as well as past trends**. Proficiency profiles are most effective when they are examined over time. An individual will benefit from understanding these patterns and using them to inform potential targets for the future.

2. **Use Career Path self-assessment to categorize and analyze past forces** (experiences, mentoring, and education and training). This data can be used to identify any clear gaps in Forces over time.

3. **Use Proficiency and Career Path self-assessments to identify a way ahead for a career.**

    - **Identify a target state**. Proficiency profiles provide a useful starting point for discussions with the organization about potential future positions – what positions make sense, what the proficiency expectation for this position are, etc. These future goals could be based on known positions within an organization (e.g. "I want to be a systems architect") or individual desire (e.g. "I am interested in this type of system"). Target states can often be clarified in discussion with a mentor or leader who understands the expectations for different types of positions in the organization as well as the individual's proficiencies.

    - **Assess gaps between current and target proficiency.** As illustrated in Section 5.8.1., once target proficiencies have been identified, they can be plotted in a proficiency profile along with current proficiency levels. This provides an easy way to visualize gaps between current and target proficiency, helping an individual understand where they need to focus their growth.

    - **Pair proficiency gaps with career path information to identify potential ways to improve proficiency.** Experiences, mentoring, education, or training are all ways that proficiencies can be improved and often a combination of forces is required to reach a target proficiency. For example, a gap in systems engineering discipline may initially be addressed by targeted training or education programs. However, a best practice identified by Helix is that this must be applied on the job immediately in order for any improvements in proficiency to become permanent. If a mentor can help guide the application of new learning in these experiences, there is likely to be additional improvement in proficiency as well. All of these considerations provide a starting point for planning and can be used to discuss possibilities with management or leadership.

Figure 3 shows expected organizational uses of *Atlas*.

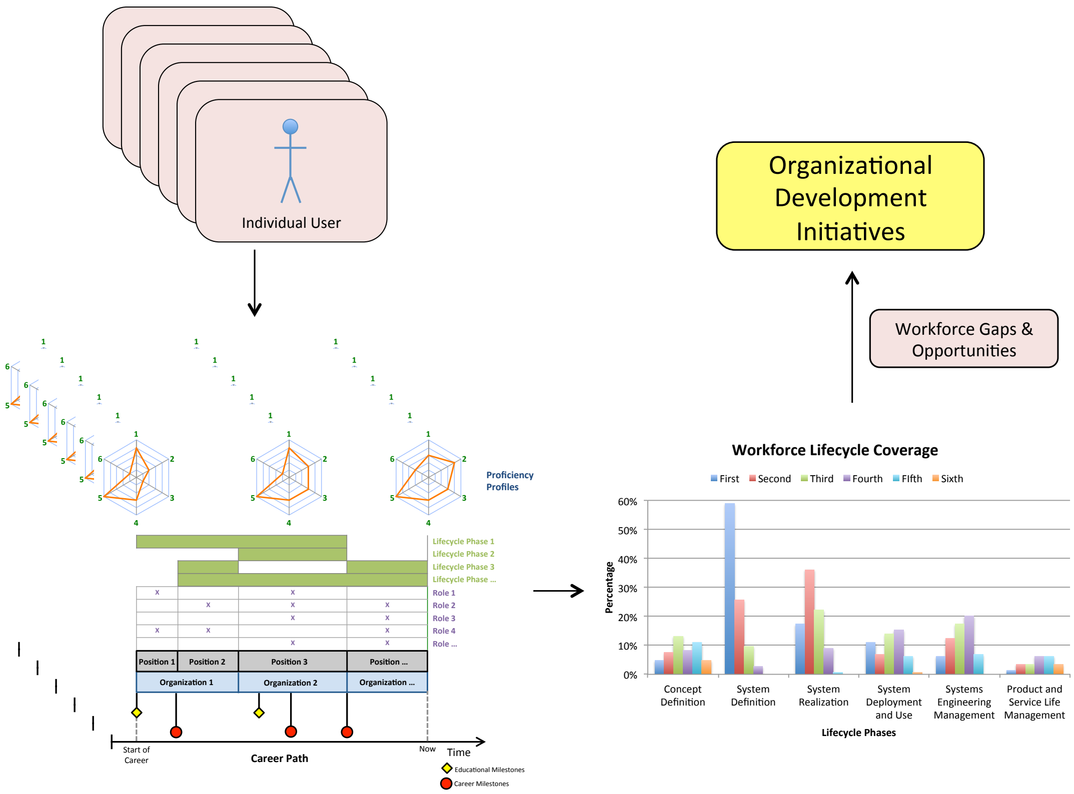


Figure 3. Expected Uses for Organizations

As shown in Figure 3, an organization is expected to be able to:

- **Treat the workforce as a collection of individuals.** Each individual can gain insight on current and potential target capabilities as discussed above. By taking the proficiency profiles – current and target – for a group of individuals, the organization can gain insight into any current capability gaps and understand desired future capabilities. For example, if no one in the group has higher than a proficiency level "6" in Technical Leadership, but the organization feels it needs several individuals with a level "8" proficiency or higher, then the organization has identified a critical skills gap. Paired with the target states, the organization can then identified individuals who are already interested in developing their Technical Leadership skills and can focus opportunities related to technical leadership on these individuals. Likewise, the organization may identify individuals who are believed to be "high potential" for technical leadership who may not have identified this in themselves and enable a conversation about future directions.

The Helix team recognizes that there is likely to be some systemic changes from viewing the workforce holistically, rather than as a collection of individuals – "the whole is greater than the sum of its parts" – but the research to date has not enabled the team to understand this. Future research will include modeling to support holistic workforce-level analysis.

- **Use the career path data from individuals to identify patterns of the overall workforce.** Similar to the point above, organizations can use the career path data for the individuals in the workforce to identify overall patterns. For example, perhaps less than 5% of the workforce has experience in the role of "Concept Creator". If the organization has identified this as a critical area for growth of systems engineers, this may indicate that the organization should develop initiatives to foster growth in this area. Likewise, if there is an area of the lifecycle that is commonly missed in the workforce, the organization can determine if this is a critical gap or whether it makes sense in the organizational context. For example, if only 10% of the workforce has experiences in "Systems Deployment and Use", but the organization does not participate in operation and maintenance of its systems, then this may be seen as acceptable. The organization also now has data about the workforce that it can use to fill gaps. For example, if the organization needed perspective on a project specific to "Systems Deployment and Use", the data will provide insight on who in the organization has this experience.

- **Use workforce data to improve or create new organizational development initiatives.** Using the gap analysis across current and future desired capabilities, the organization can identify opportunities or set strategic goals regarding workforce capability. As illustrated in the examples above, this information would then provide opportunities for improved or new development initiatives.

1.2 About This Document

This document was developed with these two user stories in mind, which is reflected in the structure below. In addition, the team believes that sharing examples of organizations that have utilized *Atlas* is important; some of these stories are collected together and others are woven throughout. The major sections of this document include:

- **2: *Atlas* 1.1 Overview**: While the details of 1.1 can be found in a separate document, this section provides an overview of the theory. This provides critical context to understand the recommendations provided through this document. Where additional detail about the model is required to elucidate recommendations, the detail is provided within the text of the other sections.

- **3: *Atlas* in Use**: This section provides insights and user stories from organizations that have publicly participated presented this information.

- **4: Using Atlas 1.1 for Individuals:** This section provides guidance for individuals who wish to use *Atlas* for their own personal growth and development. It incorporates feedback received by the Helix team from individuals who have participated in Helix or

who reached out to the team to share their questions and experiences; no individuals are named.

- **5: Using *Atlas* 1.1 for Organizations**: This section provides guidance for organizations who wish to use *Atlas* to help guide and grow their systems engineers. It includes examples from the organizations highlighted in Section 3 by name. There are additional examples organizations which have participated and provided feedback on their experiences but not spoken publicly; these are anonymous.

- **6: Conclusions:** This section provides a brief overview and example of what it could look like for an organization to implement *Atlas*.

Paper-based tools, references, and additional guidance are contained in the appendices. The Excel-based tool and the guide for use can be found at www.sercuarc.org/projects/helix.

2 ATLAS 1.1 OVERVIEW

Atlas is a set of general principles and ideas that relates to the subject of what makes systems engineers effective and why. In doing so, *Atlas* also provides insights into how individuals can develop into effective systems engineers throughout their careers and what organizations can do to support this development.

2.1 *ATLAS* OVERVIEW

The overview of *Atlas* in the context of an individual systems engineer employed in an organization is captured in the systemigram illustrated in Figure 4. A systemigram consists of nodes that contain noun phrases, links that contain verb phrases, and is to be read as sentences along the direction of the arrows. The primary sentence is read from the top left node to the bottom right node and presents the main theme of the systemigram. In the ensuing discussions, sentences to be read in the systemigram are italicized, where nodes are represented in square brackets.

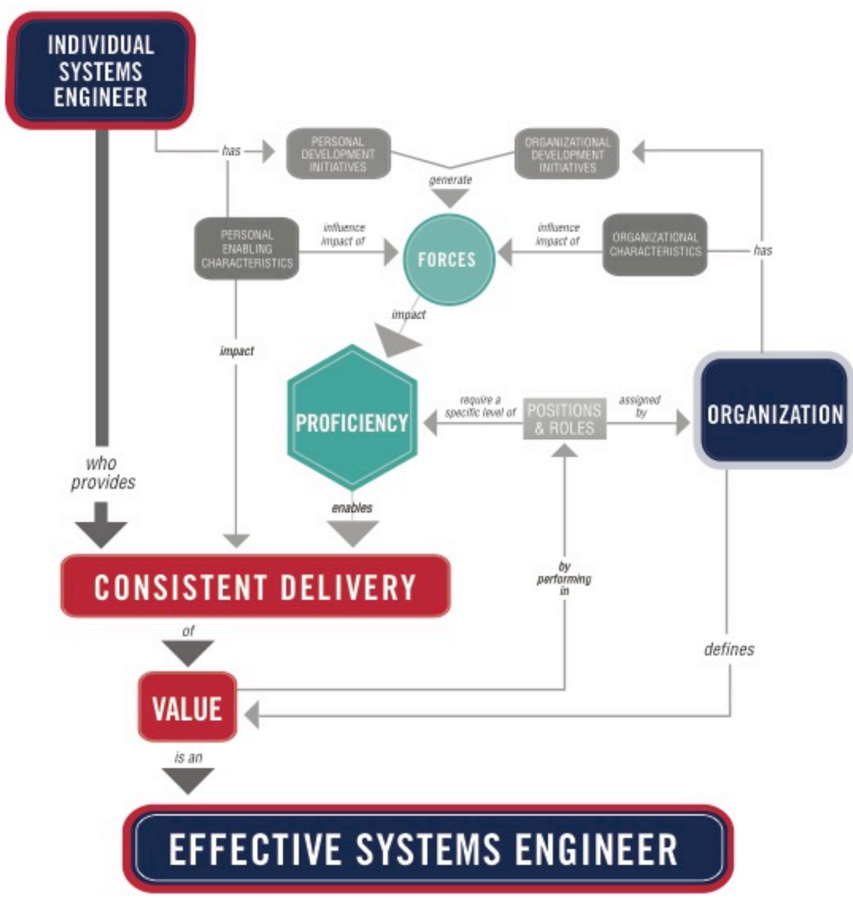


Figure 4. *Atlas 1.1*

From Figure 4 above, it can be seen that the main theme of *Atlas* is: '*[Individual Systems Engineer] who provides [Consistent Delivery] of [Value] is an [Effective Systems Engineer]*'. This fundamental definition of an effective systems engineer hinges on *[Value]*, and it can be seen that '*[Organization] defines [Value]'*. Therefore, it is on the organization to define the value that the systems engineer is expected to provide. Further, the individual systems engineer provides '*[Value] by performing in [Positions and Roles] assigned by [Organization]*'. Therefore, it is again on the organization to establish the position of the systems engineer in terms of roles and responsibilities, keeping in mind that '*[Positions and Roles] require a specific level of [Proficiency] that enables [Consistent Delivery] of [Value]*'.

The core of *Atlas* is the proficiency of the individual systems engineer – what proficiency means, and how it can be improved. '*[Individual Systems Engineer] has [Personal Development Initiatives]*' and '*[Organization] has [Organizational Development Initiatives]*'; together, they '*generate [Forces] that impact [Proficiency]*'. At the same time, '*[Individual Systems Engineer] has [Personal Characteristics] that influence the impact of [Forces]' and '[Organization] has [Organizational Characteristics] that influence the impact of [Forces]'* – these forces may have a positive or a negative influence. Further, both personal enabling characteristics and organizational characteristics '*impact [Consistent Delivery] of [Value]*'; again, the impact can be positive or negative. Amidst all these influences and impacts, the challenge for the individual systems engineer and the organization is to improve the '*[Proficiency] that enables [Consistent Delivery] of [Value]*' to the organization.

2.2 Dynamic Aspect of *Atlas*

The *Atlas* overview illustrated in Figure 4 can be considered as a quasi-static snapshot in time, but many of the elements of *Atlas* are dynamic in nature. The level of proficiency of an individual systems engineer is not fixed, but is constantly changing due to the impact of forces over time. Similarly, other elements of *Atlas*, including characteristics and initiatives of the individual systems engineer and of the organization, continue to change over time. Further, as the level of proficiency of an individual systems engineer increases over time, the organization is likely to place that systems engineer into different positions.

This dynamic aspect of *Atlas* is not captured in the overview, but is reflected in the career paths of individuals over time, where an individual's career path is the precise combination of the forces they undergo in the positions and roles they perform in over their entire career.

Leading up to the publication of *Atlas 1.0*, the Helix team defined methods to depict and analyze the career paths of systems engineers and used those methods to analyze the systems engineers in its interview sample, and how those systems engineers are shaped by the impact of forces and positions and roles over time. This is notionally represented in Figure 5.

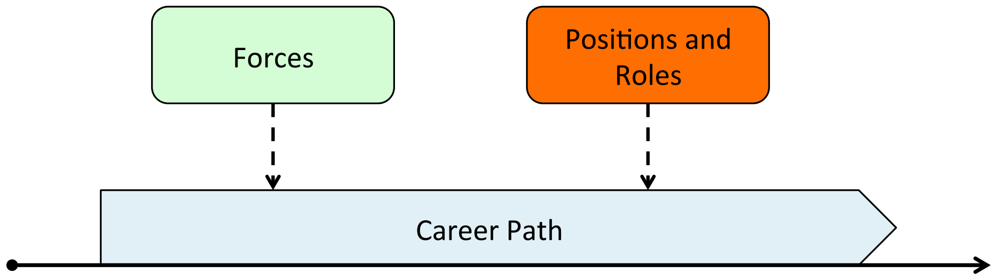


Figure 5. Career Path: A Dynamic View of *Atlas*

The Helix team has defined methods to depict and analyze the career paths of systems engineers. The team used those methods to analyze the systems engineers in its interview sample and to understand how those systems engineers are shaped by the impact of forces and positions & roles over time. These are reflected in the companion *Career Path Guidebook*.

3: EXAMPLES OF *ATLAS* IN USE

Over the last several years, many organizations have shared their experiences in using *Atlas* with the Helix team. Since some organizations have spoken publicly about their participation and implementation, it allows the team to also openly acknowledge their involvement and findings. Otherwise, under strict IRB protocol and to also allow the greatest openness within the interviews, the team prohibits mention of participating organizations. Below are five summarized examples of *Atlas* in practice by alphabetical order of the organizations. Additional details from these organizations, including slides presented publicly, are available in the Helix Workshop reports, which can be found at http://www.sercuarc.org/projects/helix/

3.1 ARDEC

The Systems Engineering Directorate (SED) in the Army Research, Development, and Engineering Center (ARDEC) became involved with Helix in 2014. Mr. Albert Stanbury had been interested in the INCOSE competency framework and saw the SERC as another organization addressing the challenges in workforce development.

ARDEC SED publicly stated in Helix workshops that they participated in Helix interviews, and the participants ranged from junior to senior with about half participating in follow- up interviews. Their interview data was aggregated into the older Atlas model, which was published in November 2014. ARDEC SED was interested in understanding their population individually as it related to the general Helix interview data. A report was delivered by Helix in March 2015, which confirmed some of the things emphasized in workforce development at SED and additionally identified areas that need further improvement.

When the SED was created approximately 10 years ago, it had to first define systems engineering. Policies created tie to DoD policies for uniformity, and basic courses in systems engineering that were developed are being taught at ARDEC. Engineers encompassing a variety of experiences were brought into the department. In conjunction with Stevens Institute of Technology, they developed the systems engineering courses. These courses cover topics across the systems engineering spectrum; some courses are specific to competencies, i.e., model-based systems engineering (MBSE). A number of the participants have obtained a master's degree in systems engineering as a result of their involvement.

The new hires at SED are put through classroom and on the job training with a senior systems engineer. The organization-specific mentoring tactics are shadowing, workshops, lunch-and-learn, and training courses in mentoring. Mentors volunteer and enjoy training junior systems engineers in their area of expertise.

Several parts of Atlas are very relevant to the SED, and Mr. Stanbury reported they are being utilized from a tactical standpoint. Since its usefulness was illustrated, the team SED to pilot

certain aspects of *Atlas* implementation in September 2015, where classic engineers and managers from other departments were also interviewed. The goals of the pilot were to:

- Identify the value that systems engineering provides to engineering overall, including other departments' perspective of this value,

- Generate an understanding of the proficiencies required of key positions and the proficiencies of systems engineers in these positions, and

- Help ARDEC understand how to apply Atlas independently.

One of the primary activities conducted with ARDEC was an alignment exercise to identify appropriate profiles for standard positions using the *Atlas* model. This included working with the management team to develop standard descriptions for these positions based on the *Atlas* roles. The Helix team then worked with management team to develop an initial "baseline" proficiency profile for each position, conducted proficiency self-assessments with individuals in those positions, then compared the management expectations and individual assessments.

3.2 BAE

BAE began its involvement with Helix in 2012 under the direction of Mr. Mark Carlson. The BAE systems engineering group is a geographically diverse organization of about 700 employees. The BAE organization is forward-leaning, and as such, the workforce has a broad skill range and are encouraged to continue expanding their expertise by completing coursework and lunch-and-learns. The workforce is also provided all the tools required for systems engineering, and there has recently been a major push towards model-based systems engineering.

When he joined the department in 2012, one of Mr. Carlson's first observations was that new graduates were struggling with basic systems engineering principles. Since then, employees with less than 10 years of experience have been moved back to the organizational area related to their core or educational background, often in classic engineering. At BAE, there is a requirement for individuals to understand their core professions fully before broadening to become systems engineers.

BAE now manages and tracks skills, focusing on growing people internally versus hiring in new systems engineers. They center on positions that have critical skills – such as chief engineers – and grow and develop the necessary competencies internally. Although employees are aligned with a specific track, they are free to work on other assignments; e.g., there are SMEs who focus on a particular technology and provide support that is different to that of systems engineering within the organization.

The workforce profile is bimodal at BAE, with primarily junior and senior systems engineers, and so an advisor program was devised to grow junior systems engineers into mid-level systems engineers more rapidly. Many senior systems engineers volunteered to be advisors and career coaches for the junior employees. They provide guidance and play a big part in the peer review

board (PRB) process that provides recommendations on nominations into systems engineering positions. This has had a positive effect on individuals because of its transparency.

Mr. Carlson explained that although some of these approaches were underway before the Helix recommendations, the Helix suggestions aligned and provided external validation for the planned changes.

3.3 MITRE

For the workshop in 2017, Dr. Rob Pitsko and Ms. Laura Ricci from MITRE provided a presentation on how MITRE responded to and planned to utilize the findings of Atlas.

To provide background, MITRE participated in Helix interviews during 2015, and has subsequently held a series of Helix review meetings in 2016, initiating a pilot of Atlas. During 2016, Dr. Pitsko and Mrs. Ricci provided insights on the expected approach to using Atlas at MITRE, and the MITRE and Helix team members discussed potential use cases, parsing the contents of Atlas to discuss areas where additional tailoring could be required. Some tailoring was already expected – particularly to the proficiency model – to make Atlas more suitable to the MITRE organizational context. MITRE used the proficiency self-assessments to inform conversations between systems engineers and their managers to better inform career planning. Dr. Pitsko and Mrs. Ricci held a focus group with MITRE systems engineers, and then progressed to a pilot used in the fall. The goals of the pilot included:

- Gauging the effectiveness of proficiency self-assessments for career planning/development,
- Understanding how *Atlas* aligns with the MITRE systems engineering competency model, which is also to be updated, and
- Providing insight back to the Helix team.

These discussions were deeply helpful to the Helix team. For example, dialogue on how MITRE may need to tailor the proficiency model to align with their organizational context, their existing competency model, and their Systems Engineering in the Modern Era (SEME) initiative helped the Helix team more clearly define where and how tailoring is expected and where the proficiency model is going to be stable for future organizations.

After the goals of the focus group were realized, MITRE did not want to completely change what they were doing to apply *Atlas,* but instead to see how some elements, particularly the proficiency framework, could be used to improve the workforce development efforts already occurring. They wanted to start with one question: Can this profile help us to have a consistent conversation?

In 2016, MITRE started a pilot to utilize the *Atlas* proficiency framework as a means to enhance its Clear Conversations – the process by which employees and their managers review progress and construct a plan for career development. First, the management and senior leadership in the Systems Engineering Technical Center at MITRE reviewed the framework and tailored it to be more specific to the MITRE context, incorporating areas of the competency model MITRE already had including adding a proficiency area for SEME (Systems Engineering in the Modern Era) topics. In the pilot, a select group of individuals were asked to complete a tailored proficiency profile prior to their Clear Conversation with their manager. The manager then would review the profile to give clear and consistent feedback (a common technique for 360° reviews). Once the employee and manager agreed on a baseline, they could then map out a target profile – areas in which both agreed the employee should work on growing in the future – and a path for that development.

MITRE then collected feedback on how well the use of the proficiency profiles worked, and whether it was worthwhile to continue. Based on the feedback, MITRE is expanding the pilot to additional employees.

3.4 Rockwell Collins

There was a historical joint effort between Rockwell Collins and the Stevens Institute of Technology to provide systems and software engineering education at Rockwell Collins, at the time Rockwell Collins decided to participate in the Helix project. The systems engineering department has been comprised of a mix of new-hires, recent graduates, and employees from varying departments interested in systems engineering. It was noted that new graduates were generally not successful as systems engineers. Within Rockwell Collins, aerospace engineers seemed to make the transition to systems engineering best; they have to study many different aspects of engineering to understand engineering the aircraft as a whole and Rockwell Collins believes that this systems-level perspective may be what facilitates their transition. Mr. Mark Gries, mentioned during a Helix workshop that at Rockwell Collins systems engineers are well compensated monetarily, which provides additional incentive for classic engineers to move into the systems engineering department. For the past five or so years, there has been a concerted effort to improve systems engineering at Rockwell Collins, and *Atlas* seemed like a useful tool to assist in the effort. Mr. Gries identified several aspects of *Atlas* that Rockwell Collins has found to be useful:

1. There is a notion that some people do not have the systems engineering mindset, where some aspect of big picture thinking may be inherent. Because of this, not all good engineers will make good systems engineers. Training is not enough to cultivate this proficiency; experiences and mentoring are also required as well as personal enabling characteristics. Rockwell Collins finds *Atlas* very helpful in explaining how this critical skill can be developed.

2. Recognition that the organization plays a major role. There are certain things an organization can do to inhibit systems engineers for being as effective as they could be. At Rockwell Collins, specifically, there is no centralized systems engineering department; there are many different systems engineering organizations throughout other departments. This makes it difficult to have consistency in delivery mechanisms, and it is difficult to engage systems engineers from multiple departments together to talk about discipline.

3. The comprehensive *Atlas* proficiency model provides the nuts and bolts of systems engineers' core skills, and Rockwell Collins believes this is a good tool to put in front of a worker to discuss his or her profile and any changes needed for career advancement. This facilitates a better discussion between the manager and the engineer to work together and forge a path ahead.

Rockwell Collins is planning to use *Atlas* to help the organization move from a generic performance and time-based assessment and advancement approach to a more competency-based one. Progression and advancement have historically been based on time spent in the position and generic annual performance reviews. While this is not a terrible surrogate for competency, this process does not provide satisfactory feedback for the employee. Competency-based progression requires metrics and it has to be simple enough that people can understand it. Ideally, it would also help to develop and improve training content to recognize and develop what it means to have skill mastery for systems engineers. Rockwell Collins believes that the Helix proficiency model is a very good resource to support their approach.

The ideal Rockwell Collins system engineer is built in many ways, from experience in multiple roles to learning the domain. It takes about five years to develop expert understanding of a domain, and their leadership believes that junior systems engineers feel this is too a long time. The leadership perceives that if junior systems engineers were provided a better roadmap for how to develop themselves, it would be extraordinarily helpful and would represent the benefits of focusing in a specific area for a longer period of time.

Rockwell Collins likes the notion of being able to sit with an employee and give them a set of expectations of how to grow across their careers. This is not relevant only to the systems engineers, but for all engineers. They believe that the concepts and framework of *Atlas* are transferrable, though the details will change and be tailored for classic engineers.

3.5 Rolls-Royce

As with many organizations that have utilized *Atlas*, *Atlas* was not the initial step Rolls-Royce took to understand or improve its systems engineering workforce. Rolls-Royce had an existing competency model for systems engineering prior to the Helix work. However, *Atlas* provided a useful point of comparison; Rolls-Royce compared the *Atlas* proficiency model and the Rolls-Royce competency model to see if there were any gaps or adjustments needed. Likewise, the

Helix roles provided a useful point of comparison between the *Atlas* systems engineering roles and the specific roles defined in the organization.

Rolls-Royce's end objective is that at some point systems engineering practices get embedded into their practices and internalized to the extent that they do not have to talk about "systems engineering." As stated by Mr. Richard Beasley at the 4th Helix Workshop, "The goal is not to talk about systems engineering, it's that that's just the way we work." Comparing their competency model with that of *Atlas* helped guide approaches to address normalizing systems engineering methodologies throughout workforce.

One of the areas of note from this work is that every engineer should have soft skills so people can holistically understand the status of development efforts, to which Rolls-Royce was pleased to see the further breakdown of the proficiencies discussed in *Atlas*. The core competencies every engineer must have at Rolls-Royce include:

- Technical Communications
- Planning/Project/Program Mining
- Systems Thinking
- Curiosity

These align with several of the skills and personal characteristics of *Atlas*. In addition to the core competencies, Rolls-Royce has between six and ten competencies for each "role." (Beasley, 2012) (Note: in Rolls-Royce, "role" denotes a specific job, which would be a "position" in *Atlas*.) In addition, there are four levels of expertise in the organization (Aware, Supervised Practitioner, Practitioner, Expert) and they are considering creating a fifth level between "Practitioner" and "Expert" to indicate senior practitioners. This aligns with the updated five-level proficiency rubric in *Atlas* 1.1.

4: USING *ATLAS* 1.1 FOR INDIVIDUALS

This section contains general guidance on using *Atlas* for self-assessment and planning for individuals to guide their own self-assessments and growth.

4.1 PROFICIENCY

One of the aspects of *Atlas* that has resonated greatly with individuals is the proficiency model. It provides insight into the knowledge, skills, abilities, behaviors, and cognitions required for systems engineers to be effective.

4.1.1 ATLAS PROFICIENCY MODEL

The *Atlas* proficiency model consists of six proficiency areas based on the Helix interview data, as shown in Figure 6 below.

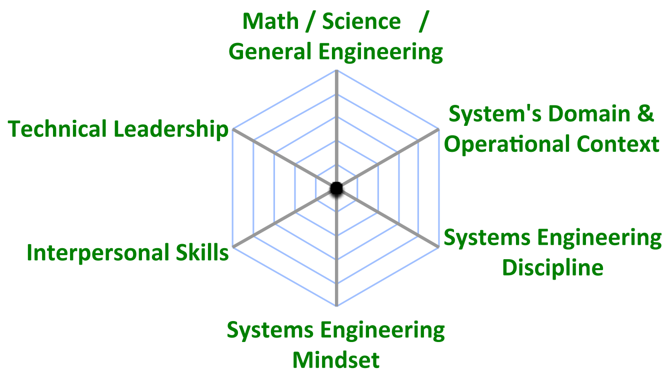


Figure 6. Proficiency Areas for Systems Engineers

1. ***Math/Science/General Engineering:*** Foundational concepts from mathematics, physical sciences, and general engineering;
2. ***System's Domain & Operational Context:*** Relevant domains, disciplines, and technologies for a given system and its operation;
3. ***Systems Engineering Discipline***: Foundation of systems science and systems engineering knowledge;
4. ***Systems Engineering Mindset***: Skills, behaviors, and cognition associated with being a systems engineer;
5. ***Interpersonal Skills***: Skills and behaviors associated with the ability to work effectively in a team environment and to coordinate across the problem domain and solution

domain; and

6. ***Technical Leadership***: Skills and behaviors associated with the ability to guide a diverse team of experts toward a specific technical goal.

Proficiency areas 1 to 3 consist of primarily technically based skills, while proficiency areas 4 to 6 consist primarily of the interdisciplinary skills. The six proficiency areas in *Atlas* are further divided into categories and, in some cases, into topics, as shown in Table 1.

Table 1. Atlas Proficiency Areas, Categories, and Topics

Area	Category	Topic
1. Math / Science / General Engineering	**1.1.** Natural Science Foundations	
	1.2. Engineering Fundamentals	
	1.3. Probability and Statistics	
	1.4. Calculus and Analytical Geometry	
	1.5. Computing Fundamentals	
2. Systems' Domain & Operational Context	**2.1.** Principal and Relevant Systems	< List of Principal and Relevant Systems >
	2.2. Familiarity with Principal System's Concept of Operations (ConOps)	
	2.3. Relevant Domains	< List of relevant Domains >
	2.4. Relevant Technologies	< List of relevant Technologies >
	2.5. Relevant Disciplines and Specialties	< List of relevant Disciplines and Specialties >
	2.6. System Characteristics	< List of applicable System Types, Scales, and Levels >
3. Systems Engineering Discipline	**3.1.** Lifecycle	**3.1.1** Lifecycle Models **3.1.2** Concept Definition **3.1.3** System Definition **3.1.4** System Realization **3.1.5** System Deployment and Use **3.1.6** Product and Service Life Management
	3.2. Systems Engineering Management	**3.2.1** Planning **3.2.2** Risk Management **3.2.3** Configuration Management **3.2.4** Assessment and Control **3.2.5** Quality Management
	3.3. SE Methods, Processes, and Tools	**3.3.1** Balance and Optimization **3.3.2** Modeling and Simulation **3.3.3** Development Process **3.3.4** Systems Engineering Tools
	3.4. Systems Engineering Trends	**3.4.1** Complexity **3.4.2** Model Oriented Systems Engineering **3.4.3** Systems Engineering Analytics **3.4.4** Agile Systems Engineering

Area	Category	Topic
4. Systems Engineering Mindset	4.1. Big-Picture Thinking	
	4.2. Paradoxical Mindset	4.2.1 Big-Picture Thinking and Attention to Detail 4.2.2 Strategic and Tactical 4.2.3 Analytic and Synthetic 4.2.4 Courageous and Humble 4.2.5 Methodical and Creative
	4.3. Adaptability	
	4.4. Abstraction	
	4.5. Foresight and Vision	
5. Interpersonal Skills	5.1. Communication	5.1.1 Audience 5.1.2 Content 5.1.3 Mode
	5.2. Listening and Comprehension	
	5.3. Working in a Team	
	5.4. Influence, Persuasion and Negotiation	
	5.5. Building a Social Network	
6. Technical Leadership	6.1. Building and Orchestrating a Diverse Team	
	6.2. Balanced Decision Making & Rational Risk Taking	
	6.3. Guiding Diverse Stakeholders	
	6.4. Conflict Resolution & Barrier Breaking	
	6.5. Business and Project Management Skills	
	6.6. Establishing Technical Strategies	
	6.7. Enabling Broad Portfolio-Level Outcomes	

For additional detail on the proficiency model, please see *Atlas* 1.1. (2018, SERC-2018-TR-101-A)

4.1.2 ASSESSING PROFICIENCY

One area that has proven more difficult than expected for the Helix team is the development of a rubric to guide assessment of proficiencies. The team has helped over 100 individuals conduct self-assessments and had exploratory conversation around these assessments, but the primary roadblock to this has been that individuals struggle to explain skills versus how they attained them.

For example, if an individual said that they were a 6 out of 10 for "Systems Engineering Discipline", the team would ask what that "6" really meant. The answers would often be something like this: Well, I've been doing systems engineering for 5 years and I've seen most of the lifecycle and I am good with the tools we utilize here. Note that "I've seen most of the lifecycle" – an aspect of their career path – is different from "I am able to provide clear value and leadership at any stage of the lifecycle." When the team probed further, individuals simply did not have the vocabulary to describe precisely the differences between a "5 out of 10" and a "7 out of 10".

In their work to be published in 2018, Pyster, Hutchison, and Henry tackled this in a different way. They identified a comparable proficiency scale – utilizing broad descriptions for general levels of proficiency – rather than trying to tailor a specific definition for every single topic. Their rubric is adapted from a rubric developed by the National Institutes of Health (NIH). The "NIH Proficiency Scale is an instrument used to measure one's ability to demonstrate a competency on the job." The rubric includes five proficiency levels, titled 'Fundamental Awareness' to "Expert'." Pyster et al. have adapted this to apply to the Atlas framework, as illustrated in Table 2. (2018, in print)

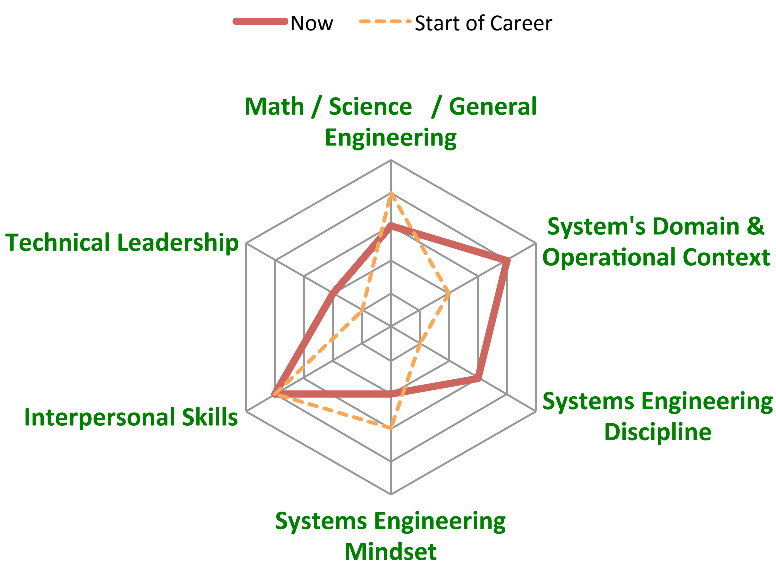
Table 2. Proficiency Levels (adapted from Pyster et al. 2018, in print, used with permission)

#	Level	Level Description
1	***FUNDAMENTAL AWARENESS***	Individual has common knowledge or an understanding of basic techniques and concepts. Focus is on learning rather than doing.
2	***NOVICE***	Individual has the level of experience gained in a classroom or as a trainee on-the-job. Individual can discuss terminology, concepts, principles, and issues related to this proficiency, and use the full range of reference and resource materials in this proficiency. Individual routinely need help performing tasks that rely on this proficiency.
3	***INTERMEDIATE***	Individual can successfully complete tasks relying on this proficiency. Help from an expert may be required from time to time, but the task is usually performed independently. The individual has applied this proficiency to situations occasionally while needing minimal guidance to perform it successfully. Individual understands and can discuss the application and implications of changes in tasks relying on the proficiency.

#	Level	Level Description
4	***Advanced***	Individual can perform the actions associated with this proficiency without assistance. The individual has consistently provided practical and relevant ideas and perspectives on ways to improve the proficiency and its application and can coach others on this proficiency by translating complex nuances related to it into easy to understand terms. Individual participates in senior level discussions regarding this proficiency and assists in the development of reference and resource materials in this proficiency.
5	***Expert***	Individual is known as an expert in this proficiency and provides guidance and troubleshooting and answers questions related to this proficiency and the roles where the proficiency is used. Focus is strategic. Individual have demonstrated consistent excellence in applying this proficiency across multiple projects and/or organizations. Individual can explain this proficiency to others in a commanding fashion, both inside and outside their organization.

During some of the Helix interviews in 2015-2017, interviewees were asked to self-evaluate their level of proficiency based on the *Atlas* proficiency model, at the Area level. Generally, interviewees evaluated themselves on a level of 1 to 10, where 1 was 'least proficient' and 10 was 'most proficient'. This was a subjective scale and hence when someone placed themselves at an 8 for a proficiency area, for example, it was based on their personal interpretation on what it meant. These self-evaluations – and subsequent discussions on why interviewees scored themselves in a particular way – are expected to provide insights in future research towards defining those objective scales.

Interviewees were asked to evaluate their proficiencies at two points in time: (1) at the time of the interview, and (2) at the start of their career. This enables a proficiency profile to be plotted, as illustrated in Figure 7.



A note for all proficiency profiles in this document: these profiles all follow the standard methodology for radar diagrams. Each axis demonstrates the data for that particular proficiency area. The center represents a value of "0" with each level outward indicating a step up on the proficiency level. (i.e. the first ring is "1/Novice" and the last ring is "5/Expert".

Figure 7. Proficiency Profile of an Individual

The proficiency profile is not meant to be exact since the self-evaluations are subjective, and individuals may have over-evaluated or under-evaluated themselves. Also, 'Start of Career' could be as recent as five years ago for one individual or twenty-five years ago for another. However, this exercise enables a discussion around the relative strengths in specific proficiencies; how proficiency levels changed over time; and what factors or forces caused or enabled those changes.

The primary intent of *Atlas* is not to just understand the current state of effective systems engineers, but to support the development of future systems engineers who will be effective. From a proficiency perspective, it would mean setting target levels for proficiency areas, as illustrated in Figure 8.

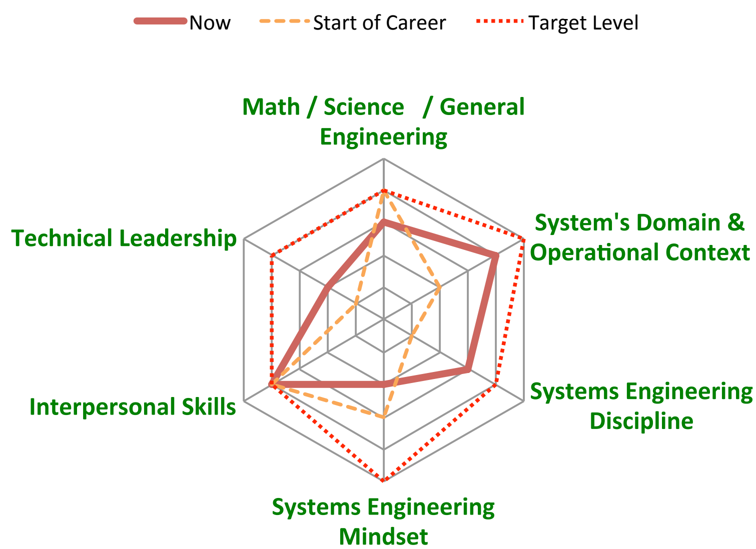


Figure 8. Proficiency Profile with Target Levels

4.1.3 Creating Retrospective Proficiency Profiles

Many people want to jump into the Atlas proficiency model by focusing on their current effectiveness. However, the Helix team recommends that an individual actually start by creating retrospective proficiency assessments. Why is this important? This helps an individual in a number of ways. Unlike current assessments, retrospective assessments feel less "high stakes" – less likely to potentially impact current and future job prospects. Therefore, people are more likely to rate themselves lower on retrospective proficiencies; i.e. they are less likely to suffer from overestimation which plagues most self-assessments. They also provide an excellent opportunity for an individual to get comfortable with the proficiency model, with a chance to build consistent understanding and application of the different proficiency levels in a no-risk way.

To build a retrospective proficiency model, the Helix team recommends that one pick a specific point in time, generally around a distinct milestone such as graduation with a bachelors or

masters degree, a first systems engineering position, etc. It can be helpful to review your resume or CV to remember exactly what your career path had looked like to date. Then you will tailor the proficiency model, build your understanding of the rubric, and perform your self-assessment. If possible, getting external validation about your assessment is very helpful. Most of these steps may be iterative.

1. **Tailor the Model**. For each of the proficiency areas, review the list of categories. For categories that are broken into topics, identify the key topics that were most important at this point in your career. Note that this may change over time. For example, an individual may start in a large defense company for which physics and calculus are critically important topics and later work at a medical device company where biology and chemistry become more heavily weighted. In addition, certain proficiencies may have been more critical than others at this point in time, which can also be noted. Use this approach to create a tailored version of the proficiency model. In Figure 6, this is illustrated in the following ways: highlighted categories were seen as the most important in each area; greyed out categories were seen as not relevant for this position; "handwritten" notes highlight the specifics for categories that were most important for this point in time.

2. **Build Your Understanding of the Rubric**. The rubric highlighted in Table 2 is relatively simple. However, spend some time coming up with examples to help you internalize each of these. The following all proved to be useful techniques during self-assessments supported by the Helix team:

    a. **Internal Exploration**

        i. **Think about a mentor who you respect.**

        ii. **Think about a peer who you work with frequently.**

        iii. **Think about someone at your organization who is/was more junior than yourself.**

    How would you rate these individuals in these areas? Why? What does it mean, specifically, that one is a "5/Expert" in systems engineering discipline or a "2/Novice" in technical leadership? How does this compare with other individuals of similar seniority? The key here is to think of specifics. This will help guide you when you think about your own capabilities.

    Atlas utilizes a 5-point scale, but this is still qualitative. Some individuals have preferred to use a 10-point scale or using decimals, to allow for additional granularity (e.g. "I am Expert in some categories and Advanced in others for this proficiency area; I want to show that I am between the levels, so I will record a 4.5"). This is fine and particularly if you are using the proficiency model only for your own internal understanding, the scale itself is less important than using it consistently. There are a few items worth noting: using too many decimal places implies a precision that does not really exist in these types of qualitative

assessments. For example, in one self-assessment when we were using a 3-point scale, an individual rated himself as a “2.75”. When asked what this meant, it was that he “was not yet the best, but was definitely a top performer”. But the two decimal places implied that there was a lot more quantitative rigor to the assessment than existed in reality. The Helix team recommends the 5-point scale outlined in Table 2, but if you prefer more granularity, we encourage you not to use more granularity than half-steps (e.g. 1.5, 2.5, etc.) or to use a 10-point scale. And, if you are performing your self-assessment as part of a larger effort within your organization, it is important to utilize a consistent scale; your organization should provide guidance on this. (see Section 5.3)

b. **Group/External Exploration -** “I had said I was a ‘4’ in this area, but if you are a ‘4’, then I am not more than a ‘3’. Did I over-rate myself or did you under-rate yourself?” This was the common type of discussion in Helix self-assessment group sessions.

   Because many of the self-assessments for the Helix project were done in small groups, it was common as individuals shared their own insights and ratings for others to adjust their assessments. Ideally, the rubric will create a consistent expectation for ratings. But the truth is, that it is still somewhat subjective. The conversations around differences in levels led to conversation around understandings of what the definitions for the levels really mean in context. It is important, if you choose to do group exercises for this kind of work, that you select a group of individuals with whom you have already built trust, as open communication is critical.

3. **Self-Assess**. Using the tailored proficiency model and the understanding you’ve built of the different proficiency levels outlined in Table 2, perform your own self-assessment. Figure 6 is an example of a completed self-assessment using the paper-based tools.

   In Figure 6, the individual noted that this was for when she completed her undergraduate degree and began her first job. In five of the six proficiency areas, the individual highlighted what she believed was the most important category for her at the time. In some areas, grey text indicates areas which she believed were not relevant to her position at the time. It is not surprising that with several categories not relevant at the time, she did not highlight a category of highest importance in the “Technical Leadership” area.

   The self-assessments for this point in time are also included in Figure 9, and in this case reveal a few common patterns – after graduate the highest proficiency was considered in Math/Science/General Engineering, with strong skills in Interpersonal Skills and Systems Mindset.

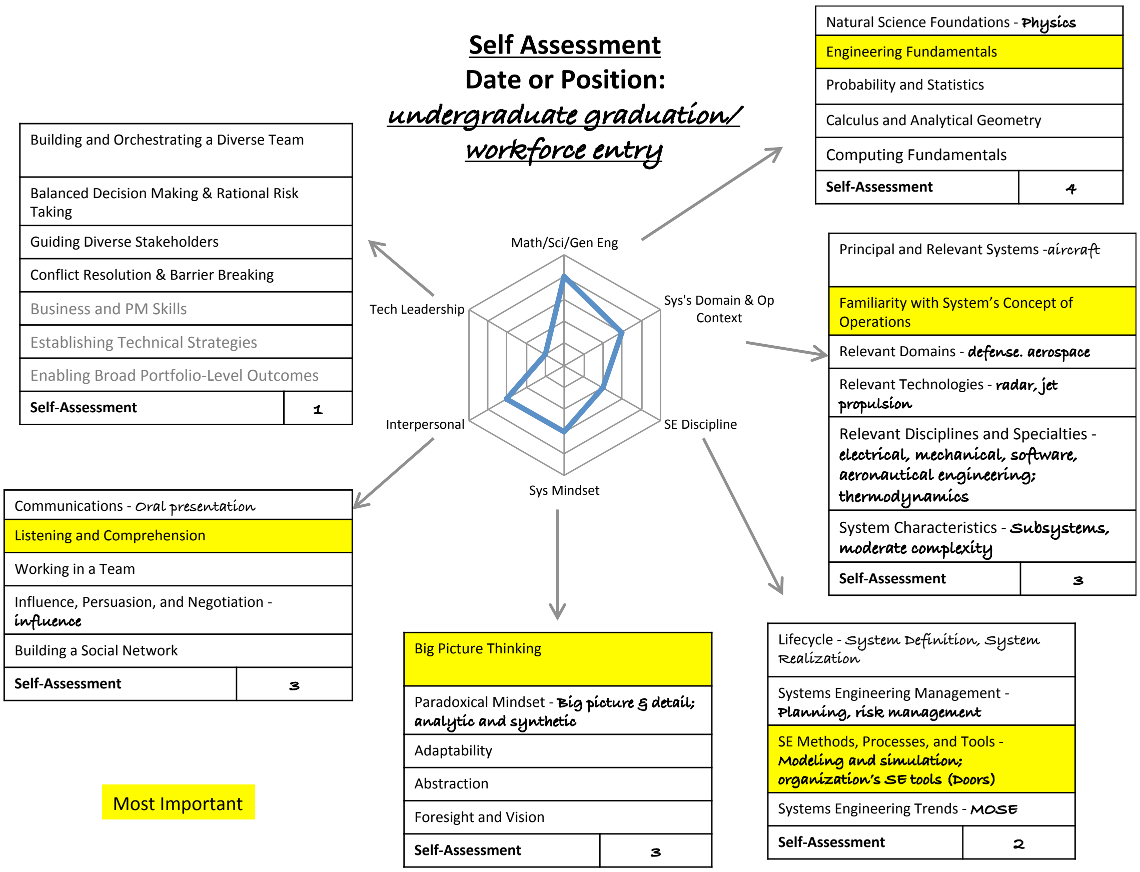


Figure 9. Retrospective Self-Assessment Example

4. **Validate with Feedback.** It may seem unusual that an individual would rate themselves as "Advanced" in any area immediately after graduation, but in fact this was quite common. Part of the reason is that individuals often do not realize their own limitations in their earlier careers. As the saying goes, "They don't know what they don't know." This is the reason that finding some way to get feedback or do some baselining can be so important. A trusted peer, mentor, or supervisor can provide valuable feedback that, again, helps to build internal consistency in how the rubric is applied.

Note that this assessment is stated as if it would be performed in isolation. In fact, systems engineers grow based upon their career paths. *Atlas* also includes guidance on how to characterize and assess one's career path (see Section 4.2). In practice, the Helix team has done career profiles both before and after proficiency assessments. There was not a clear "best" way to do this. Usually after an individual completed a career profile, they could more readily identify how they had grown or changed in proficiency over time, but generally this did not change their proficiency assessments. Please refer to the Career Path Guidebook for additional insights on the relationships between career path and proficiency.

The past profile is helpful for many reasons. Charting a few retrospective proficiencies can be very helpful in identifying areas of growth, stagnation, or even lessening of skills over time. This gives a historical perspective that can help someone more accurately gauge their current

proficiencies (see Section 4.1.4) and have a better basis for planning future proficiency goals (see Section 4.1.5)

4.1.4 Creating a Current Proficiency Profile

The current proficiency is the area that most Helix participants have been most interested in exploring, specifically asking the questions, “How am I doing?” and “How do I stack up against my peers?” For the latter, the Helix team is working on building a web-based tools that would allow anonymized data collection and comparison for any individuals who use the tool and agree to be included. For the former, the proficiency model provides a useful tool to give individuals insight.

The process for creating a current proficiency profile are the same as creating a retrospective one: tailor the proficiency model, build your understanding of the rubric, perform your self-assessment, and validate with feedback.

1. **Tailor the Model**. If you started with a retrospective profile, you already have at least one tailored version of the model. However, you should still review to determine whether your tailored version(s) is as applicable now as it was in the past and update as appropriate. In the example discussed earlier, perhaps you worked in a large aerospace and defense corporation and now you work in a company that makes medical devices. It would be expected that the model would change; in particular the topics chosen for “systems domain and operational context” may be very different, with medical and physiological specialties becoming more important and technologies such radar becoming irrelevant in your new position.

2. **Build Your Understanding of the Rubric**. As stated previously, this is important for internal consistency and to help you review patterns in your growth and change over time. There are no changes in how this done from the discussion above.

3. **Self-Assess**. Again, perform your self-assessment based on your *current* performance. Figure 10 shows an example of how the individual whose profile you reviewed in Figure 6 might have grown over her career.

   When your self-assessment is completed, it is useful to understand your own changes over time as well as how this compares with other systems engineers. For example, note that in Figure 10, the Math/Science/General Engineering proficiency actually decreased; in the retrospective assessment it was a “4” or “Advanced”, and in the current assessment it is a “3” or “Intermediate”. This is a common pattern, as individuals move from positions focused on roles like detailed design to positions where roles such as Systems Architect or System Integrator become more prevalent. In other words, there is a baseline of required Math/Science/General Engineering skill to be able to work with engineers and lead engineering work – but when your position emphasizes other skills, it is natural that these may decline slightly as other skills grow.

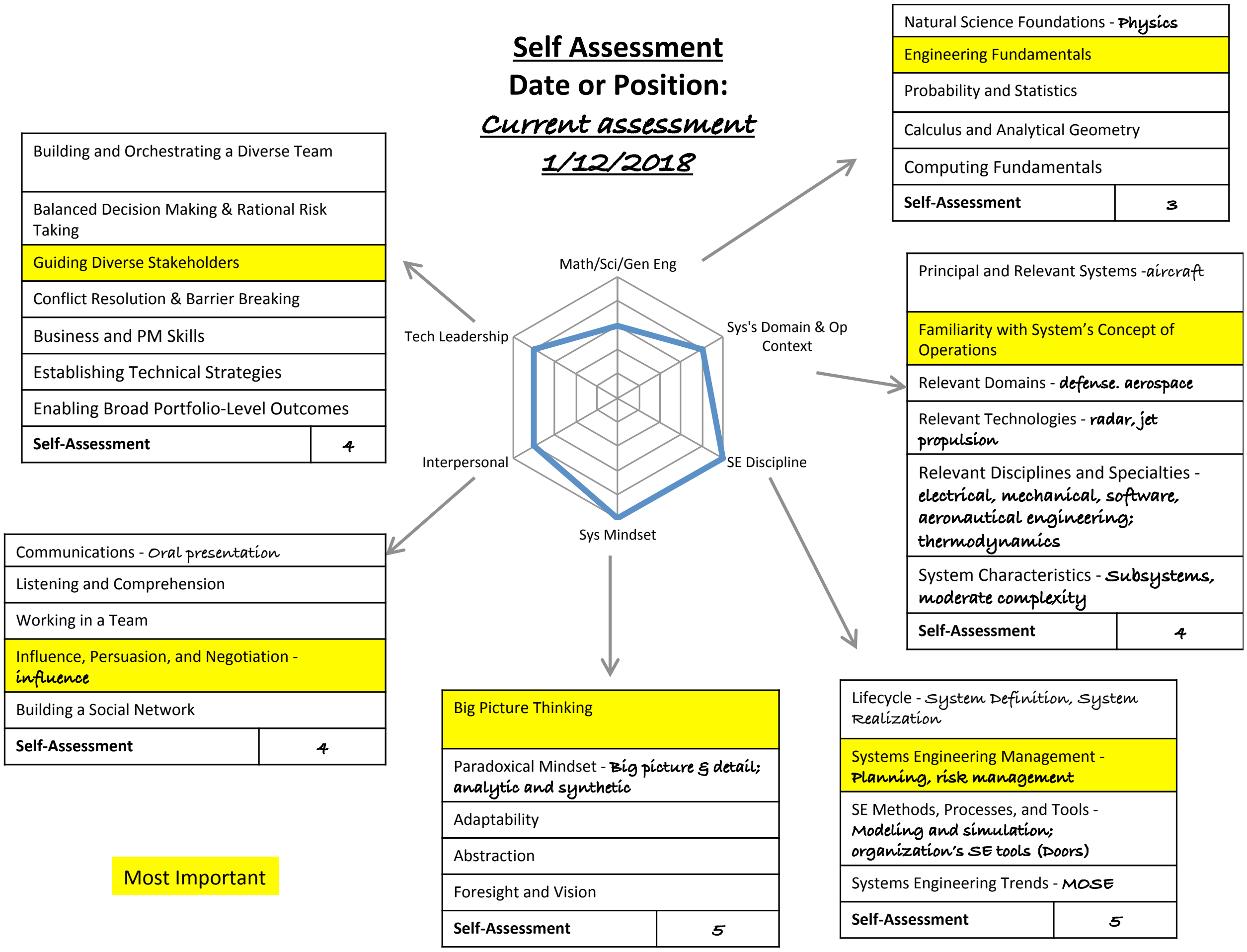


Figure 10. Example Current Proficiency Profile

4. **Validate with Feedback.** Getting some external validation and feedback on current proficiency is perhaps more critical than on retrospective profiles. This helps you get a sense of where you are today and will help you "fill the gaps" in any blind spots you might have about your performance. Again, trusted peers, leaders, or managers are all excellent individuals to give you feedback and help you adjust your profile or mature your rationale for your ratings.

The current profile is useful not only from improving your self-awareness but also to provide a solid base on which to plan your future growth.

4.1.5 Creating a Target Proficiency Profile

A prerequisite for creating a target proficiency is creating your current proficiency. Without this basis on where you are, it will be very difficult to create a realistic growth path. For example, if

you are creating a target for one year away and you identify that you want to be a “5” or “Expert” in Systems Engineering Discipline, but you do not realize that you are currently at a level “2”, you may not understand that you are setting unrealistic goals for yourself.

The process for creating a target proficiency profile is the similar to creating a retrospective or current one: 1) tailor the proficiency model, 2) build your understanding of the rubric, 3) identify realistic targets, and 4) validate with feedback. Because steps 1 and 2 are the same, please review the information above.

The real difference here is identifying what your target should be, as opposed to assessing where you are or were. There are a few critical inputs for this:

- **How far out are you targeting?** Generally, the Helix team has worked with individuals to create target profiles from one to five years out from the current time. Beyond that, it is difficult to judge what may be realistic.

- **What are your interests?** The first question to ask yourself when creating a target profile is, what are you actually interested in? What kind of work keeps you engaged and what becomes drudgery. This does not mean that you can create a world where every moment of your professional life is exciting. But understanding where your interests lie can be useful in guiding your career. As one senior systems engineers who participated in Helix stated, “I thought I would enjoy being a systems engineering manager [an organizational manager responsible for systems engineers]. It did not take me long to realize that this was not a good fit for me and I quickly looked for a new position that would put me back into technical work.”

  This question of whether to focus on technical versus more supervisor work, for example, is a common issue that many junior- and mid-level systems engineers in Helix reported struggling with. For many, they had to explore positions in both areas to understand each more clearly and make the decision. However, for the purposes of thinking about proficiency, it is important because it will determine whether you will focus on growing systems engineering proficiencies or whether there are other proficiencies around management that will become important to you.

- **What are your options?** Some organizations provide guidance on career paths and examples or descriptions of positions that you may aspire to. Some organizations do not offer these materials, but your manager, supervisor, or mentor should be able to help you understand these positions for your organization. For example, is there a position such as “Chief Systems Engineer”, defined by Helix as the technical conscience and primary technical authority for a system? Are there Chief Architects or Systems Engineering Leads? Organizations will use different titles, but understanding what the more senior positions are and what they entail will provide critical information for your planning.

It is important to note that for your future planning, you do not have to look only within your organization. Professional societies like INCOSE (International Council on Systems Engineering)

or IEEE Systems Council can be a good resource to understand the state of practice for systems engineering and what types of positions may exist.

When you understand which types positions may be of interest to you in the future, you can start to explore what proficiencies are necessary to be effective in those positions. For example, you might sit down with a Chief Systems Engineer and talk to them about their daily activities and what it takes to do the job well. Again, mentors and supervisors can also provide a wealth of information on this. Some organizations may even provide example profiles for individuals in specific positions. For example, MITRE has asked several of its senior systems engineers to create and share their proficiency profiles and career paths. When individuals are planning, they can use these as a reference not as an absolute "right" profile, but as guidance on areas where they may want to focus their efforts to grow.

As with the retrospective and current profiles, it is important to have some external validation of this career path. This is an opportunity not only to ensure that the growth path you have created is realistic on your timeline and starting from your current proficiency, but if you work with your supervisor to validate your target, it is also an opportunity to build buy-in with him on the ways in which you can realistically growth. (See Section 4.2, below)

4.2 Career Path

The Helix team has developed a *Career Path Guidebook*, which provides the common patterns, findings, and FAQs around career paths from the nearly 200 individuals with whom Helix has these common patterns, please refer to this companion document. The Helix team has also created templates that individuals can use to assess their career paths – paper based (Appendix B), Excel-Based (http://www.sercuarc.org/projects/helix), and web-based. Whatever tool you use, it is important to:

- Characterize the career path by position (which is mapped to time),
- Provide the organizational context for each position,
- Classify each position by a number of variables.

Career paths are most effective when they are pared with proficiency self-assessments, which can help identify patterns over time. (see the *Atlas Career Path Guidebook* for additional information)

4.2.1 Assessing Your Career Path

Atlas outlines many variables that were discussed repeatedly as factors in how individuals grew in their careers. These factors are grouped into the three main Forces of *Atlas*: experiences, mentoring, and education and training. Because education is often the easiest Force for individuals to understand – they know where they want to school and what they studied and when – the *Guide* starts with education to help individuals get into the mindset before tackling the other Forces.

4.2.1.1 Characterizing Systems Engineer's Education

Education plays two key roles in the development of systems engineers. First, it provides the foundation knowledge to support engineering-related work. Typically, this takes the form of undergraduate education in an engineering discipline, technical field, or physical science. Second, graduate level education is an avenue to develop more advanced skills, explore more in-depth knowledge, and help systems engineers grow as they move through their careers.

To characterize education patterns, the following academic information was extracted for each systems engineer in the sample:

- **Date:** The date of the completion of the degree program.
- **Type of Degree:** This is the level of education an individual achieved. The categories used were: bachelor's, master's, and doctor of philosophy (PhD). For this analysis, only education that resulted in a degree was recorded. Individuals did receive graduate certificates or took individual courses, but there was not enough data to draw any meaningful conclusions. Also, if a degree was in progress but not completed, it was not recorded.
- **Field of Study:** The primary discipline on which the individual's education was focused. These were initially recorded as reported. Over time, categories of related fields of study were created.

4.2.1.2 Characterizing Systems Engineer's Experiences

Experimental literature on experiences has primarily focused on two metrics for experience: time (e.g. Ford et al. 1993; Schmidt et al. 1986; Firth 1979; Davidz 2006) and the frequency of times a specific task or activity of interest was performed. Additional literature classifies human subjects based on their experiences – which is subtly different than classifying the experiences themselves – often using a combination of time and the frequency of tasks performed. This approach may also include considerations for specific roles played, Kor 2003, Kirschenbaum 1992). Additional literature in the field of systems engineering, such as Sheard's "Twelve

Systems Engineering Roles" (1996) or the Graduate Reference Curriculum for Systems Engineering (GRCSE) (Pyster et al. 2012) indicate, though, that the characterization of experiences is critically important to understanding how experiences enable growth.

The first challenge is to determine a common "unit of measure" for experience. Though time is common, it is not easily used in the data available. For example, if someone described a position they held over a five-year period, they did not explain the portion of time taken up by the activities they performed over those five years. In addition, several individuals submitted information on their careers that included detailed descriptions, but did not include markers for chronological time. Because of these data limitations, the Helix team chose to use a position as the unit of measure for experience.

Based on both the literature and the Helix data itself, each position has several characteristics:

- **Relevance:** A 'relevant' position is one that enables a systems engineer to develop the proficiencies critical to systems engineering.

- **Position**: Every systems engineer who is employed at an organization fills a position that is established by the organization; that organization also defines the roles and responsibilities to be performed. Helix considers position as a 'unit of measure' for experience, since most of the characteristics of experience are in the context of the position that is held. A 'systems engineering' position is one where the individual's primary focus was on systems engineering activities.

- **Date**: includes a starting and ending year. It reflects the amount of time spent in a position.

- **Lifecycle Stage** Generic systems engineering lifecycle phases considered in Atlas are based on the lifecycle phases in the Guide to the Systems Engineering Body of Knowledge (SEBoK). (SEBoK Authors 2015). Phases include: Concept Definition, System Definition, System Realization, System Deployment and Use, Product and Service Life Management, and Systems Engineering Management.

- **Roles** describes the related systems engineering activities performed at the position held. Helix team identified 16 systems engineering roles which include: Concept Creator, Requirements Owner, System Architect, System Integrator, System Analyst, Detailed Designer, V&V Engineer, Support Engineer, Systems Engineering Champion, Process Engineer, Customer Interface, Technical Manager, Information Manager, Coordinator, Instructor/Teacher.

- **Number of Organizations:** The number of different organizations that an individual has worked at, not counting internal movement within an organization across departments or divisions, reflects the variety of types of experiences that one may possess. The three organizational sectors identified are government, industry, and academia.

- **Systems:** There are many aspects to the types of systems on which a systems engineer could work. Working across these different categories provides valuable experience to an individual systems engineer.
    - **Domain:** This is the primary area of application for the systems being worked on. However, there are many domain categorizations; some domains also relate to industry sectors.
    - **Type:** Product systems, service systems, and enterprise systems are three major types of systems, depending on the nature and composition of the system of interest. System of systems is another paradigm in systems engineering, and could be a combination of one or more types of systems.
    - **Level:** A systems engineer could work on various levels of a system: component/element, subsystem, system, and platform or system of systems.

The ways in which positions were categorized were pulled from existing literature wherever possible. For example, a systems engineer working in the commercial sector of a company may define lifecycle in different terms than those used by a US Department of Defense systems engineer. To normalize the discussion, the definition of life cycle stages from the Guide to the Systems Engineering Body of Knowledge (SEBoK) was used; the interviewee's own words and phrasing were compared with the descriptions of life cycle stages in the SEBoK and categorized appropriately. (BKCASE Editorial Board, 2017) Likewise, the roles played by the interviewees were based on Sarah Sheard's "Twelve Roles of Systems Engineers" (Sheard, 1996), although roles have been added to reflect what was seen in the data. Where existing literature was not available, categories were created that reflect the character of the data.

By using the data available for each individual, the characteristics of each position played and the order that they played them can be identified. Then, the information can be used to develop a preliminary understanding of how career paths shape proficiency.

4.2.2 Identifying Key Positions

A third aspect of career paths are the key milestones for a systems engineer's career. The Helix team focused on major steps or changes in a systems engineer's positions. A position is equivalent to the roles and responsibilities associated with an individual's title. Organizations will define what roles and responsibilities each position contains and position descriptions may not translate across organizations. The key positions identified for systems engineer included:

- **First systems engineering position:** This was self-identified by participants as the first position in which systems engineering responsibilities were the primary focus of a position, though they may have non-systems engineering responsibilities as well. This was often difficult to identify, because participants indicated that their roles often

transitioned gradually and it was hard to identify when they officially became systems engineers, especially because so many never had that specific title. The Helix team recorded this information in whatever way it was provided by participants. In a few organizations, the hierarchy and structure for becoming a systems engineer was much more well-defined, and for individuals in those organizations, the transition to systems engineer was more easily identified.

- **Chief systems engineering positions.** A chief systems engineer (CSE) is someone who has formal responsibility to oversee and shepherd the technical correctness of a system, often coordinating with many other systems engineers who have smaller scopes of responsibility. These milestones are any positions in which an individual acted as a CSE, regardless of their title within their organization.

- **Project manager positions.** A project manager is someone who has formal responsibility to oversee the programmatic aspects of a system, generally focused on budget and schedule. Project management responsibilities sometimes overlap with SE responsibilities, particularly those around planning and management; in some instances, a CSE may also function as a PM.

4.2.3 Identifying Key Training

For some individuals in the Helix dataset, there were a few key training opportunities that really stood out as helping them grow. These included trainings such as week-long leadership retreats or two-week rotations into other parts of the organization. The idea here is not to catalogue every training course you have ever taken, but to highlight training that has been particularly impactful and put it on a timeline with your positions.

4.2.4 Identifying Key Mentoring

As with training, mentoring comes in many different forms. For the career path, it is useful to identify areas where mentoring was particularly prevalent and can be tied directly to growth. Examples in the Helix dataset included shadowing where a senior systems engineer sat down and explained all of the ins and outs of a legacy system or more senior systems engineers guiding individuals on how to deal with a particular customer or facet of systems engineering.

4.2.5 Career Path Timeline

Visualizing the career path can in some ways be just as helpful as the analysis described above. It is the opportunity to put all of the disparate pieces of your career path together and look at them more holistically. In working with individuals to create their self-assessments, the Helix team heard things like, “Wow. I thought I had played a lot of different systems engineering

roles, but looks at this, I need to diversify more," or "I had thought I had spent plenty of time in requirements, but now that I look at this, it has only been a small part of my career."

This is not to say that there is a "right" or "wrong" career path – but this holistic view allows you to identify gaps or overlaps in a clear way. It also provides you the opportunity to more intentionally plan your career path for the future. For example, a gap in a systems engineering role may encourage you to focus on a different project or type of work than you otherwise might. And it should be noted that gaps are not "bad"; most career paths did not include all 15 roles. But again, it allows you to determine whether this is acceptable based on your goals or whether this is something that should be addressed.

Figure 8 provides an example of a career path assessment. As you can see, pairing the career path with proficiency assessments can provide additional insight.

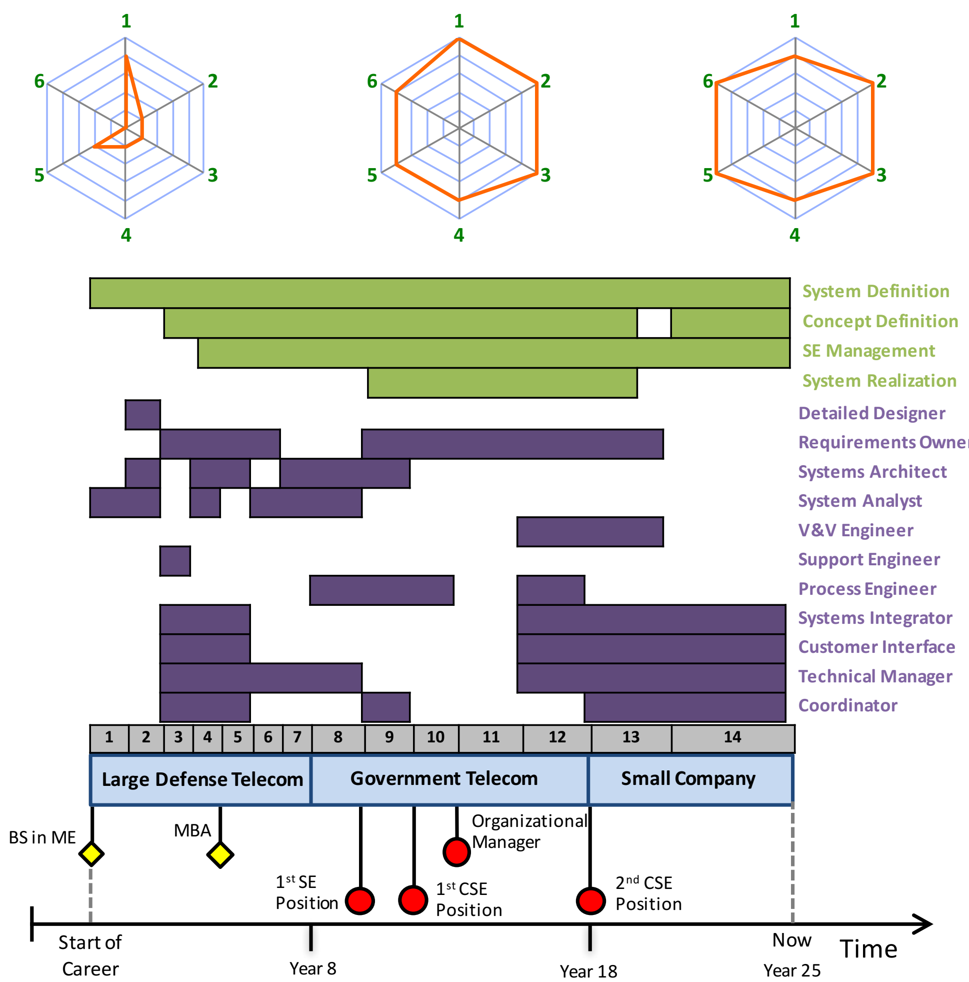


Figure 11. Example career path of a chief systems engineer from the Helix sample.

4.3 Personal Characteristics

Atlas includes seven personal characteristics that were consistently cited as important for effective systems engineers:

- **Self-Awareness:** The ability to self-reflect and become aware of one’s own strengths, weaknesses, knowledge, and lack thereof.
- **Ambition and Internal Motivation:** The desire to reach high career positions, and the ability to draw motivation and energy from within in order to accomplish those high ambitions.
- **Inquisitiveness**: Possessing a high level of curiosity, wanting to know more and have a ‘hunger for knowledge’.
- **Lifelong Learning:** Always looking to learn and to keeping abreast with latest developments in related disciplines and systems, irrespective of seniority or position.
- **Confidence, Persistence and Focus:** Possessing the confidence to interact with stakeholders irrespective of their relative seniority or positions; the ability to stand firm and not give-up; and the ability to remain focused on the success of the overall system.
- **Professionalism and Respect:** Being professional in the conduct, mannerisms, and behaviors; and treating others with respect, recognizing that other experts may possess more knowledge and experience.
- **Creativity** Systems engineers are expected to have the ability to use their imaginations, see new possibilities in the ideas of others, find important problems, seek alternative solutions, and bring novel, useful, and valuable changes into being. Creativity is a mindset; the willingness to invent, seek, and use practical tools for innovation in the face of uncertain, ambiguous, and rapidly changing conditions.

Personal characteristics are attributes of individuals that are developed over time and that can be applied broadly to all aspects of one's life. Much like proficiencies, these attributes can be enhanced through intention, attention, and practice. There are relationships between the characteristics and proficiencies. For example, the entire description of creating proficiency profiles above requires that an individual have some self-awareness – an ability to understand one’s own strengths, weaknesses, knowledge, and lack thereof. The sections above site many reasons why creating accurate proficiency profiles may be useful. If an individual is not self-aware, it will be difficult for him to assess his own proficiencies accurately. This is part of the reason that there is a “validation” step recommended – it is an opportunity for individuals to improve their own self-awareness.

While there may be a relationship between some of the personal characteristics as defined above and a variety of inventories, style tests, or personality measures you may have used to

gain self-awareness in the past, there is no one type of assessment that will help you understand where you stand on all of the characteristics. Be cautious when extrapolating from any assessment that purports to be a stable measure of "personality" including measures like Myers-Briggs and the Big Five Personality Traits inventories. While these inventories might provide a current baseline on an attribute, they are not designed to describe your actual behavior or how you are capable of behaving. "Openness to Experience", for example, in the Big Five, is defined as "imagination and insight; those high in this trait typically have a broad range of interests, are more adventurous, and creative." Using the Big Five assessment of "Openness to Experience" may give you insights that correlate to the *Atlas* personal characteristics of creativity and lifelong learning. It does not, however, show that you are currently using those attributes well or imply that you are not capable of being creative at work.

The Helix team suggests that whatever types of assessments you may have used, you can reflect upon the outcomes to develop a sense of your strengths, weaknesses and interests. To learn more about antecedents and consequences of some of these personal characteristics the team recommends that you look at recent books and videos by the following authors:

- Erica Andersen: Learning, self-awareness, curiosity, vulnerability
  - Andersen, E. (2016). *Learning to learn*. Harvard Business Review, March, pp 98-101, R1603J.
- Peter Coleman and Robert Ferguson: Skillful conflict resolution
  - Coleman, P. T. & Ferguson, R. (2014). Making conflict work. New York, NY: Houghton Miflin Harcourt Publishing Company.
- Angela Duckworth: Persistence and "Grit"
  - Duckworth, A. (2016). *Grit*. New York, NY: Scribner.
- Carol Dweck: Growth Mindset
  - Dweck, C. S. Ph.d. (2008). *Mindset.* New York, NY: Ballantine Books.
- Linda Hill, Greg Brandeau, Emily Truelove, Kent Lineback: leadership and collaborative innovation
  - Hill, L. A., Brandeau, G., Truelove, E., & Lineback, K. (June 2014). Collective genius. *Harvard Business Review*, pp 94-102. Reprint: #R1406G.
  - Hill, L.A., Brandeau, G., Truelove, E., & Lineback, K. (2014). *Collective Genius*. Boston, MA: Harvard Business Review Press.
- Tom and David Kelley: Design thinking and creative confidence
  - Kelley, T. and Kelley, D. (2013). *Creative confidence*. New York, NY: Crown Business.
- Daniel Pink: "Drive" - personal aspects of motivation including autonomy, mastery, and purpose
  - Pink, D. (2009). *Drive.* New York, NY: Riverhead Books.
- R. Keith Sawyer: Creativity and collaboration

- Sawyer, R. K. (2012). *Explaining creativity.* 2nd Edition. New York, NY: Oxford University Press.
- Sawyer, R. K. (2017). *Group genius: The creative power of collaboration*. New York, NY: Basic Books.

5: USING *ATLAS* 1.1 FOR ORGANIZATIONS

Atlas can be used by any organization that considers systems engineering – an interdisciplinary approach governing the total technical and managerial effort required to transform a set of customer needs, expectations, and constraints into a solution and to support that solution throughout its life – important to its business or mission, regardless of whether they use the term "systems engineering" or not.

Atlas 1.1 reflects that the analyses on organizational characteristics are still evolving. The organizational characteristics (culture, structure, value of systems engineering, definition of systems engineering, etc.) have shown to have a critical impact on the effectiveness of systems engineers. Most of these are addressed individually, below. However, organizational culture permeates and also has an impact on each of these factors. For that reason, organizational culture is addressed throughout this Section 5, integrated into the various topics.

5.1 IMPLEMENTATION SPECTRUM

The examples presented in Section 3 illustrated that there are a wide number of ways in which an organization can utilize *Atlas*, ranging from a "greenfield" approach, where an organization is new or new to systems engineering and uses *Atlas* to set up a workforce development approach for systems engineering, to organizations with a mature workforce development approach which will simply cross-reference their existing processes and definitions against *Atlas* and identify any possible adjustments.

The sections below are meant to help organizations utilize *Atlas* across this spectrum.

5.2 DEVELOPING AND COMMUNICATING CLEAR EXPECTATIONS ON VALUE

> *"When I get a systems engineer, I don't know what I'm supposed to be getting."*
>
> *-Anonymous Program Manager (Helix Participant)*
>
> *"A lot of our program managers don't understand what systems engineering is or what systems engineers are supposed to do."*
>
> *-Anonymous Systems Engineer (Helix Participant)*

The above quotes are just two examples of many in the Helix dataset. In fact, the team gathered quotes like this from all 22 participating organizations – although in some this was very common and in some this view was an outlier. What do these organizations all have in

common? There is some level of confusion about what capability systems engineering provides and what *value* a systems engineer provides.

There are six primary values for systems engineering defined in *Atlas*, shown in Table 3. These are listed in the order of frequency of mentions in the dataset. These reflect common values that were heard across the 363 participants and all 22 organizations that have participated in Helix and the patterns were the same in government and industry and whether we were talking to systems engineers, their peers, or their leadership.

In addition to the primary values, there are several sets of enabling values in Table 3. These are activities systems engineers perform that provide value to a project and, when combined, deliver the primary value. They are in some ways the "how" of the primary value's "what". Notice that some of the enabling values appear several times. Note that Value 2, "Translation" does not have an enabling value. This is because when the team asked how systems engineers delivered this value, they provided critical *proficiencies*, but nothing that rose to enabling values (which generally require a variety of proficiencies to deliver).

Table 3. Primary Values Systems Engineering Provide

#	Primary Values	Enabling Values
1	**Keeping and maintaining the system vision**	• Getting the "true" requirements from the customer and creating alignment between the customer and the project team. (39%) • Seeing relationships between the disciplines and helping team members understand and respect those relationships. (33%) • Balancing technical risks and opportunities with the desired end result. (36%) • Providing the big picture perspective for the system. (44%)
2	**Translation of technical jargon into business or operational terms and vice versa**	
3	**Enabling diverse teams to successfully develop systems. (10%)**	• Effectively understanding and communicating the system vision to the team, and ensuring that the team is aligned with this vision. (38%) • Helping the team to understand the big picture perspective and where they fit within the larger picture. (38%) • Identifying areas of concern for integration in advance. (13%)
4	**Managing emergence in both the project and the system (7%)**	• Projecting into the future (14%), which includes staying "above the noise" of day-to-day development issues and identifying pitfalls. • Technical problem-solving balanced with the big picture perspective. (43%)

#	Primary Values	Enabling Values
5	**Enabling good technical decisions at the system level (7%)**	• The ability to see the vision for the system and communicate that vision clearly is a key enabler to helping teams make good technical decisions. (40%) • The big picture perspective is critical for understanding the system holistically and enabling system-level technical decisions, versus decisions made at the component or sub-system level. (22%) • A systems engineer's solid grasp on the customer's needs is also a critical enabler to ensuring that decisions made will keep the system on the correct technical path. (22%) • Being able to bring together a diverse team of engineers and subject matter experts is also critically important. (26%) • A systems engineer's problem solving abilities – particularly the ability to focus on root versus proximal cause – is also a key enabler. (26%).
6	**Supporting the business cases for systems (7%)**	• Balancing traditional project management concerns of cost and schedule with technical requirements. (41%) • Understanding the position of a system within the organization or customer's portfolio and communicating this to the team. (59%)

Not every systems engineer will provide every value at all times. Some values may be more critical for some parts of an organization than others. **Setting clear expectations for which values an organization wants systems engineers to provide is a critical first step to maturing the view of systems engineering in an organization.** An organization does not have to simply select from the values in Table 3; they can and should tailor their expected values to match the goals and capabilities desired of systems engineers in their organization. Once the values are identified:

- They need to be clearly communicated within any systems engineering organization, to leadership, and to peer groups. Many systems engineers who participated in Helix reported having to "fight for a place at the table" with other engineers, program mangers, etc. In fact, this was so pervasive that is prompted the Helix team to add a systems engineering role to *Atlas*: Systems Engineering Champion. The confusion around the values that systems engineers provide greatly influences this. In fact, at organizations where there was a high level of confusion about these values, almost every participating systems engineer reported playing the "Champion" role. At organizations where this was much less common, fewer individuals reported needing to play this role.

  A second item to note on communicating the values is that in a handful of organizations in the sample, there were value statements available and leadership believed that these were clearly communicated. They were surprised to learn how little these values were understood by different engineering specialties, program managers, etc.

- The values should become part of the way systems engineers are assessed and rewarded. Even organizations who had clear value expectations for systems engineers did not always have assessment or rewards systems that aligned with them. When the team asked, “How are you assessed?” almost all systems engineers described the traditional and generic “annual review process” and stated that none of them were assessed based on systems engineering specific factors. The few who were described these as individual goals generated between themselves and their managers. But overall, it was uncommon for value delivery to be included in assessment.

  Likewise, systems engineers (as with any employee) want to be rewarded for exceptional work. Many individuals highlighted organizational practices that not only do not reward systems engineering work, but systemically reduce the importance of systems engineering by placing a higher value on conflicting actions. One of the best instances of this was the “hero culture” described in several organizations. Individuals described being rewarded for “putting in long hours and not sleeping for the last several weeks of a project”. When the Helix team asked if there were similar rewards for the kind of up-front planning systems engineering provides, they explained that if a program goes well, it is almost anticlimactic. Most explained there are no rewards for the types of systems engineering activities that allow a program to avoid pitfalls and control costs.

5.3 Utilizing Proficiency Profiles

In Section 4.2 (above), the team explains how an individual can develop a proficiency profile. This section explains how organizations can utilize proficiency profiles for their systems engineering workforce development efforts.

5.3.1 Tailoring the Proficiency Model

As with the recommendations for individuals, the Helix team recommends that organizations begin by reviewing and tailoring the proficiency model. Some organizations will already have a competency model or similar assessment of skills for systems engineers. The recommendation is not that *Atlas* replace these existing models but that they at least be compared to *Atlas* to create a gap assessment. This way, if an element of the *Atlas* proficiency model is going to be left out, it can be an intentional decision and not an oversight. Two notional examples of how this might look can be found in Table 4. Note that in addition to tailoring the categories and topics, Organization 2, also added a new category to “Math/Science/General Engineering” related to Social Sciences, specifically psychology and sociology.

Table 4. Tailoring the Atlas Proficiency Framework

Area	Category	Organization 1: Defense Aerospace	Organization 2: Medical Devices
1. Math / Science / General Engineering	1.1. Natural Science Foundations	Physics considered most critical	Chemistry and Biology considered most critical Physiology added as a Foundation
	1.2. Engineering Fundamentals	<no tailoring>	<no tailoring>
	1.3. Probability and Statistics	<no tailoring>	<no tailoring>
	1.4. Calculus and Analytical Geometry	Both are considered critical	Considered less critical than Probability & Statistics
	1.5. Computing Fundamentals	Considered less critical than the other categories	Considered critical for integration with Electronic Health Records (EHRs)
	1.6. **Social Sciences**		Sociology and Psychology
2. Systems' Domain & Operational Context	2.1. Principal and Relevant Systems	Air-breathing jet engines Military aircraft	Magnetic Resonance Imaging (MRI) X-Ray Computerized Tomography (CT)
	2.2. Familiarity with Principal System's Concept of Operations (ConOps)	Expectations about the level of familiarity may differ (e.g. understanding basic in-flight operations)	Expectations about the level of familiarity may differ (e.g. actual experience in a clinical setting to understand use cases, how system fits within the healthcare environment, where its use may fit in an overall process, etc.)
	2.3. Relevant Domains	Aerospace	Healthcare
	2.4. Relevant Technologies	Radar Sonar Navigation Systems	MRI X-Ray CT
	2.5. Relevant Disciplines and Specialties	Mechanical Engineering Electrical Engineering Aerospace Engineering Software Engineering Thermodynamics Aerodynamics Ergonomics	Electrical Engineering Mechanical Engineering Biomedical Engineering Software Engineering Ergonomics Radiation Safety
	2.6. System Characteristics	System level design with understanding of the system of systems in the operational environment	Systems of systems level design enabling integration with other medical devices and healthcare IT systems
3. Systems Engineering	3.1. Lifecycle	• V-lifecycle approach emphasized	• Spiral/Incremental Development lifecycle

Area	Category	Organization 1: Defense Aerospace	Organization 2: Medical Devices
Discipline		• Organization not involved in in-service operation and maintenance (full handoff after delivery)	model emphasized • Organization heavily involved in in-service operation and maintenance
	3.2. Systems Engineering Management	<no tailoring>	<no tailoring>
	3.3. SE Methods, Processes, and Tools	• Heavy emphasis on modeling and simulation • Emphasis on operational safety	• Heavy emphasis in optimization for patient safety
	3.4. Systems Engineering Trends	• Model Oriented Systems Engineering	<no tailoring>
4. Systems Mindset	4.1. Big-Picture Thinking	<no tailoring>	<no tailoring>
	4.2. Paradoxical Mindset	• Balance of Methodical and Creative heavily weighted	• Paradoxical mindset heavily weighted
	4.3. Adaptability	<no tailoring>	<no tailoring>
	4.4. Abstraction	<no tailoring>	<no tailoring>
	4.5. Foresight and Vision	<no tailoring>	<no tailoring>
5. Interpersonal Skills	5.1. Communication	<no tailoring>	<no tailoring>
	5.2. Listening and Comprehension	<no tailoring>	<no tailoring>
	5.3. Working in a Team	<no tailoring>	<no tailoring>
	5.4. Influence, Persuasion and Negotiation	<no tailoring>	<no tailoring>
	5.5. Building a Social Network	<no tailoring>	<no tailoring>
6. Technical Leadership	6.1. Building and Orchestrating a Diverse Team	<no tailoring>	<no tailoring>
	6.2. Balanced Decision Making & Rational Risk Taking	<no tailoring>	Risk is viewed negatively by this highly safety-conscious organization; this becomes focused on decision making.

Area	Category	Organization 1: Defense Aerospace	Organization 2: Medical Devices
	6.3. Guiding Diverse Stakeholders	<no tailoring>	<no tailoring>
	6.4. Conflict Resolution & Barrier Breaking	<no tailoring>	<no tailoring>
	6.5. Business and Project Management Skills	• Project management is treated as a distinctly separate discipline from systems engineering in this organization. There is cultural pressure not to include this as a "systems engineering" proficiency.	<no tailoring>
	6.6. Establishing Technical Strategies	• N/A (Systems engineers do not set the technical strategy for the organization)	• Only expected for senior systems engineers
	6.7. Enabling Broad Portfolio-Level Outcomes	• N/A (Systems engineers do not set the technical strategy for the organization)	• Only expected for senior systems engineers

At Rolls-Royce and ARDEC-SED, the existing competency model was reviewed against *Atlas*. ARDEC-SED, for example, explained that their current competency model covered all of the elements of *Atlas*, though they were organized differently.

MITRE worked with the Helix team to crosswalk the MITRE competency model, Figure 12, and *Atlas* proficiency model. This included in-depth discussions about each of the categories and topics and led to some updates of the MITRE competency model as well as the *Atlas* model. Specifically, it was interactions with MITRE that led to the reorganization of categories in "Systems Engineering Discipline" under the "Systems Engineering Trends" topic and to the addition of the portfolio- and organizational- level categories under "Technical Leadership."

Some areas were straightforward to align between the competency and proficiency models. For example, though organized differently, the MITRE competency model areas 2.0 and 3.0 align nicely with the Helix area "Systems Engineering Discipline". 5.0, "Collaboration and Individual Characteristics" aligns well with categories in "Interpersonal Skills" and "Systems Mindset" in the *Atlas* proficiency model as well as the personal enabling characteristics. The Enterprise perspectives of the MITRE model helped lead to the updates in *Atlas* described above. In addition, MITRE has an initiative called "Systems Engineering in the Modern Era" or "SEME".

Though not part of the competency model, this aligned well with the category “Systems Engineering Trends” in the “Systems Engineering Discipline” area.

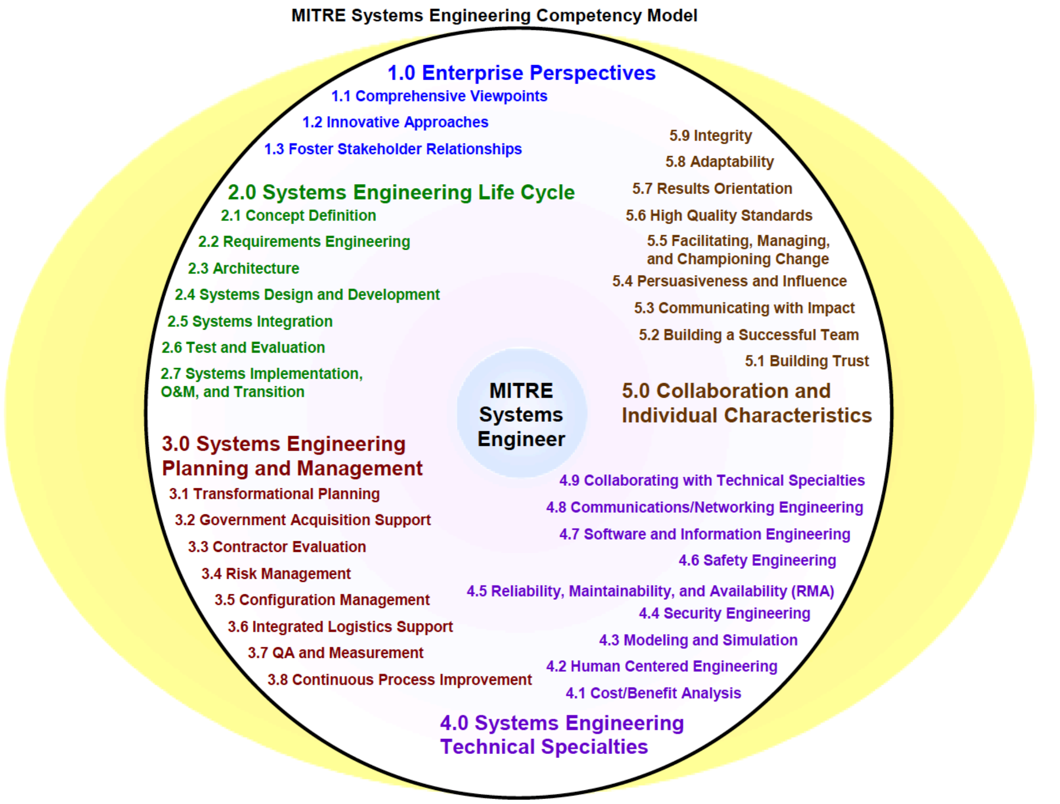


Figure 12. MITRE Systems Engineering Competency Model (MITRE 2007, used with permission)

Whether you are starting with an existing model or whether you will be starting with *Atlas*, it is important to review the entire model, looking at categories and topics, and determine whether this organization works within your organizational context and whether there are proficiencies that do not apply or which are missing from the model but important for the systems engineering work at your organizations. At MITRE, for their pilot program to utilize *Atlas* to guide their Clear Conversations, they developed a tailored proficiency model that reflects both their competency model and *Atlas*. Table 5 illustrates this.

Table 5. MITRE tailoring of Proficiency Model versus *Atlas* baseline (MITRE information used with permission)

MITRE Model for Clear Conversations	Atlas Proficiency Areas
Math/Science/General Engineering • The MITRE model adds a category for “Modeling, Simulation, and Analysis”	Math/Science/General Engineering • Modeling/Simulation/Analysis are included in “Systems Engineering Discipline” in *Atlas*

MITRE Model for Clear Conversations	Atlas Proficiency Areas
Systems Engineering Foundation • Uses “General Systems Engineering Approaches and Models”, which aligns with “Methods Processes, and Tools” in Atlas	Systems Engineering Discipline
Systems Engineering Mindset • Note that “Systems Thinking” is used – which incorporates many of the categories in the *Atlas* model • Includes Evidence-Based Systems Engineering	Systems Engineering Mindset
Systems Engineering in the Modern Era • Applied Complexity Science • Model Based Engineering • Agile SE • System of Systems Engineering • Human Machine Teaming Systems Engineering • Resilient Systems Engineering	Systems Engineering Discipline • Systems Engineering Trends category is closely related to the SEME category in the MITRE model
Interpersonal Skills	Interpersonal Skills
Technical Leadership • Includes “Understand operational domain and associated systems/technology”	Technical Leadership and Systems Domain and Operational Context

In addition to tailoring the model itself, an organization may also wish to create a weighting of specific categories or areas. For example, in some government organizations the focus is more on oversight of systems engineering activities performed by a contractor. In this environment, some of the Interpersonal Skills and Technical Leadership proficiencies may be weighted more heavily than Math/Science/General Engineering due to the nature of their work. Likewise, a small company at which systems engineers function as a “jack-of-all-trades” may decide that all proficiency areas carry equal weight.

5.3.1.1 Tailoring the Assessment Rubric

Just as the proficiency model itself should be tailored to fit the context of the organization, the rubric for assessment should be likewise tailored. For example, in some organizations a “high, medium, low” band of assessments may be preferred. In others, a “10-point” scale is more comfortable because it allows more granularity. Regardless of the scale chosen, the organization should develop a clear rubric of what it means to be at a specific level. This can be done generally, as in the *Atlas* rubric in Table 2 (above), or can be created specifically for each proficiency area. At MITRE, they developed a rubric that is specific to each area of their competency model. Table 6 provides a few selected examples from this rubric. Note that though MITRE also utilizes a five-point scale, they do not define proficiency at all five levels. They instead provide guidance on the ends of the spectrum and guidance for what it means to be in the middle. This has generally proven enough information for individuals to perform their self-assessments, with them selecting “2” or “4” if they are between the descriptions.

Table 6. Examples from MITRE Proficiency Rubric (MITRE 2017, used with permission)

Atlas Proficiency Area / Category	Proficiency Level “1”	Proficiency Level “3”	Proficiency Level “5”
1. Math / Science / General Engineering			
1.1 Natural Science Foundations	Minimal awareness of the basic concepts of physics, chemistry, and biology	Proficient in some of the principles and concepts of physics, chemistry and biology. Limited practical experience with principles	Expert in the principles and concepts of physics, chemistry and biology including practical experience, and ability to apply these in the system’s context
1.6 Modeling, Simulation, and Analysis	Minimal awareness of modeling and simulation languages and application, to include executable models. Minimal awareness of data analytics approaches and application.	Proficient in modeling and simulation languages and application, to include executable models. Proficient in data analytics approaches. Limited practical experience in their application.	Expert in modeling and simulation languages and application, to include executable models ability to readily apply these where required. Expert in data analytics approaches and ability to readily apply these where required
2. Systems Engineering Foundation	***Most Categories in this proficiency Area are divided into Topics. You may choose to assess yourself at the Category level, but it is recommended that you assess yourself at the Topic level (where available).***		

Atlas Proficiency Area / Category	Proficiency Level "1"	Proficiency Level "3"	Proficiency Level "5"
2.1 Lifecycle	Minimal awareness of lifecycle models and lifecycle stages	Proficient in the understanding of lifecycle models and how systems are developed and managed through them. An understanding of specific system lifecycle stages and inter-relationships. Limited practical experience in their application.	Expert in the understanding of lifecycle models and how systems are developed and managed though them. A deep (demonstrated/applied) understanding of specific system lifecycle stages and inter-relationships, and ability to carry out the required technical activities in each stage
3. Systems Engineering Mindset	***Most Categories in this Area are divided into Topics. Here, you may choose to assess yourself at the Category level or at the Topic level.***		
3.1 Systems Thinking ***(foundational to SEME)*** ***Note: the MITRE Rubric includes additional guidance on Systems Thinking. The Helix team is presenting only a portion of the information here for brevity.***	*WRT Big-Picture Thinking:* Minimal ability to think beyond a narrow scope of the problem or immediate timeframe at hand *WRT Paradoxical Mindset:* Minimal ability to handle seemingly opposed views, little regard of possible tension or implications across strategic and tactical concerns *WRT Flexible Comfort Zone:* Comfortable only strictly within one's comfort zone and area of technical expertise *WRT Multi-Scale Abstraction:* Minimal ability to abstract or infer from individual pieces of information and relate to environmental context	*WRT Big-Picture Thinking:* Able to think in a limited manner outside a narrow scope and immediate timeframe with some guidance *WRT Paradoxical Mindset:* Able to understand one of the opposed views separately but not both or all, able to understand either strategic or tactical implications *WRT Flexible Comfort Zone:* Able to permeate beyond one's comfort zone in a limited manner, but hesitates to explore the unknown *WRT Multi-Scale Abstraction:* Able to abstract insights with some guidance and prior experience and understand system in larger operational context	*WRT Big-Picture Thinking:* Expert in thinking broadly along various dimensions (e.g., regarding broader domain or enterprise-level considerations, and linking across apparent disparate domains such as incorporating "soft" science with "hard" science) understanding implications of near term and long term timelines. *WRT Paradoxical Mindset:* Expert in the understanding of opposed views and perspectives, ability to successfully handle them and strategic and tactical implications separately and together, and the ability to successfully move from one perspective to another *WRT Flexible Comfort Zone:* Willing and able to permeate the boundaries of one's comfort zone with ease, and able to comfortably explore the

Atlas Proficiency Area / Category	Proficiency Level "1"	Proficiency Level "3"	Proficiency Level "5"
			unknown and readily seek interdisciplinary SME *WRT Multi-Scale Abstraction:* Expert in quickly and effectively abstracting (from highly detailed level to highly conceptual level) new and significant insights from seemingly disparate pieces of information across system and environmental scales
4. *Additional* Systems Engineering in the Modern Era (SEME) Capabilities	***This Area is described at the Category level. Therefore, you should assess yourself at the Category level and Use SEME Vision Whitepaper as background on each Category.***		
4.1 Applied Complexity Science	Minimal awareness of tools, techniques, and procedures from mathematical and scientific disciplines or engineering problems of non-linearity, emergence, and unpredictability	Proficient in some tools, techniques, and procedures from mathematical and scientific disciplines. Limited ability to use to address engineering problems of non-linearity, emergence, and unpredictability.	Expert in applying tools, techniques, and procedures from mathematical and scientific disciplines to address engineering problems of non-linearity, emergence, and unpredictability and applying these to sponsor problems
4.2 Model Based Engineering	Minimal awareness of model-based engineering, business process, physics based, and operational effects modeling & simulations.	Proficient in model-based engineering, business process, physics based, and operational effects modeling & simulations. Limited practical experience in integrating them or in their application	Expert in integrating and applying model-based engineering, business process, physics based, and operational effects modeling & simulations to support engineering and management decisions throughout a system's lifecycle and applying appropriate techniques to the sponsor problems
5. Interpersonal Skills	***Category 5.1 is divided into Topics. Here, you may choose to assess yourself at the Category level or at the Topic level.***		

Atlas Proficiency Area / Category	Proficiency Level "1"	Proficiency Level "3"	Proficiency Level "5"
5.1. Communication	Minimal ability to successfully communicate any information to any audience in any mode	Able to communicate well in one predominant mode with limited familiar audience	Expert in being able to successfully and unambiguously communicate to a variety of audience and a wide range of technical and non-technical content, in various written and oral modes.
5.2. Listening & Comprehension	Minimal ability to listen to and understand others' points and perspectives	Able to listen to other's points, but limited ability to comprehend	Expert in listening and successfully comprehending others' points and perspectives
6. Technical Leadership			
6.1 Building & Orchestrating a Diverse Team	Minimal ability to form or lead a team with any success	Able to build a team with guidance but has difficulty in handling or delegating to a diverse team	Expert in bringing together the right team for the task, being able to synergistically draw individual strengths of team members, successfully leading the team to achieve end goal
6.6 Understand operational domain and associated systems/technology	Minimal understanding of domain and the systems/ technology relevant to the work program	Understands key domain terminology, mission/ business threads, CONOPs, systems and system characteristics, and technologies	Expert in leveraging understanding of domain and associated systems/ technology to anticipate future capability and technology needs
6.8 Enable broader portfolio outcomes	Not aware of portfolio outcomes associated with projects being supported	Understands key portfolio-level dependencies on MITRE data-driven products and activities.	Consistently drives toward meeting not only immediate project needs but enabling portfolio-level outcomes

Once the rubric is developed, it is important to ensure that individuals who will be using it understand and internalize it so that it applied consistently. In several organizations, the Helix team worked with small groups to discuss their rationale for different proficiency levels; through these conversations, each group developed a common understanding of how this could be applied. This kind of approach, particularly which includes feedback from the exercises to clarify and further refine the rubric is critical.

In addition, it is important to ensure that any personnel who will help guide individuals or provide feedback on creating proficiency profiles understand the rubric and the rational behind the way the rubric was generated. Managers, leaders, and mentors should all know the rubric

clearly so that they can assist individuals in creating their proficiency profiles. This is another opportunity to build a shared understanding within the organization.

Because they are subjective assessments, the profiles can only be compared qualitatively. However, by ensuring a consistent rubric that is consistently applied, the value of having profiles for your systems engineers will be increased.

5.3.1.2 Using Proficiency Profiles

Because they are qualitative, proficiency profiles can not be treated in the same way as results of a standardized test or personality assessment like Meyers-Briggs which is based on data from thousands of individuals. However, when used correctly, proficiency profiles can be very useful. In Section 4.1, individuals can find instructions on how to create a proficiency profile. This section focuses on what organizations can do with the results of those profiles.

5.3.2 Using Profiles for Individual Development

One of the ways that the Helix team first envisioned using profiles was for individual development. Figure 5 provided an example of how past, present, and target profiles can be compared. This approach is useful for individuals, but can also be very beneficial to organizations. In the Helix dataset, individuals who understood how they could grow within their organizations expressed being less likely to leave them.

In using proficiency profiles for developing individual systems engineers, it is important to pair an individual with someone they trust – this could be their manager or mentor or a leader within a team, but in order to have open conversations, there must be trust between the individuals. The leader, mentor, manager, etc. should first help by validating the individual's self-assessment. There are times when individuals simply do not yet understand their overall abilities, particularly in an individual is new to an organization or has only seen one part of an organization and has not experienced the full spectrum of proficiency levels.

Validating a self-assessment does not simply mean accepting it, but instead walking through it with the individual and discussing their rationale for their assessment. This is an opportunity to make adjustments and to provide rationale for those adjustments in turn. Once the individual and the validator have agreed to the current baseline, perhaps with some historical context via retrospective timelines, the profiles can now be used for planning.

As with validating the current profile, this is an opportunity for conversation and exploration about the potential future path of the individual. Some questions that should be asked include:

- **What is the timeline for this target profile?** Again, one to five years tends to be a reasonable timeframe. Shorter, and the individual does not have many opportunities to

grow, longer and the opportunities that will be available in five years are so nebulous, it is difficult to chart a way forward.

- **Is the target realistic?** It is particularly important to ask this question with respect to any revisions that may have been made to the "current" profile. If, for example, an individual believed he was a "3" or "Intermediate" in Systems Mindset and wanted to reach "4" or "Advanced in two years, that may be reasonable. If, however, the current assessment was updated to reflect a current proficiency of "2" or "Novice", this goal may be unattainable in that time frame.

- **What are the most critical areas for growth?** In several exercises where the Helix team guided individuals through this exercise – typically targeting three years out – individuals reported wanting to grow in all areas by several levels. Realistically, that is unlikely. It may become important, therefore, to identify areas where an individual can focus their efforts as well as areas that are important, but perhaps should be tackled later.

- **How can the organization help the individual meet her goal?** This is a critical step because it is about the actions an organization can take to help ensure the growth of its systems engineers. There are many ways to grow, but all of the Forces highlighted in *Atlas* should be considered. Some useful questions include:

    - **What experience opportunities can be identified?** In some organizations the team worked with, there was a great deal of latitude allowed for movement within an organization to gain different types of experiences. In others, this was seen as "disloyal" and despite the learning that might be gained, was likely to hamper an individual's career at least for a time. The culture of the organization will be an important consideration for this.

      With that in mind, it is important to explore what opportunities the individual may have to gain new experiences that will help them grow in the targeted area. In the Helix data, 100% of the 363 participants agreed that experience was the number one Force for growing systems engineers, so exploring the potential experience opportunities within the organization will be a critical part of helping an individual plan how to reach her target.

        - **Is there a rotational program or short assignment that might help an individual grow in these areas?** Many organizations have these types of programs and individuals who participated in them reported that they were useful for their growth not only during the assignment itself, but also later, as they reflected on those experiences in the context of another part of the organization or system. Often, these are "high potential" programs, which means the organization may not be able to guarantee a specific individual a spot in the program. However, they were viewed by Helix participants as good ways to rapidly grow certain

proficiencies, particularly, the System's Domain and Operational Context area, the Lifecycle category of the SE Discipline area, and the Big-Picture Thinking category of the Systems Mindset area.

- **Can mentoring help the individual to grow in some of these areas?** Mentoring, the second Force of *Atlas*, was the second-most-cited method for growth by systems engineers in the Helix dataset. There are many different facets of mentoring (please see *Atlas 1.1* for a detailed explanation). Many of the individual systems engineers who completed target proficiency profiles with the Helix team stated that in order to grow, they needed to find a mentor in a particular area. As an organization, you can help individuals find the right mentors who may help them grow in specific areas. Note the caveats on mentoring noted in *Atlas* 1.1, such as the criticality of matching individuals with common interests, personalities which are amenable to guidance and instruction, etc.

- **Are there specific training programs or courses that might help this individual grow?** Every organization the team worked with had some sort of training program. Some had programs specifically focused on systems engineering – ranging from a one-hour lunch-and-learn to a one- or two-week immersive course. The point is that there may already be training courses that will help individuals grow in specific areas and it makes sense to identify these as part of the target planning session.

  Note that there were several factors highlighted in *Atlas* that impact the efficacy of training and one of the more critical ones here is that for an individual to maintain any gains in proficiency from a training course, the learning needs to be applied on the job relatively quickly. So planning a course that would help an individual grow, but which will actually be used for some time is unlikely to be helpful in the long term.

- **Is education an appropriate method for growth in the critical area(s)?** Every organization in the Helix sample had some sort of educational program. They ranged from simple tuition reimbursement programs to systems engineering cohorts – collections of individuals who were simultaneously seeking a masters degree in systems engineering. Regardless of the type of program, it is worth reviewing whether academic coursework (as opposed to training) might be an appropriate way of helping an individual grow desired proficiencies.

  In general, in the Helix sample junior and mid-level systems engineers were more likely to pursue academic programs to improve their systems engineering proficiency. Most senior systems engineers stated that they were "too senior" for a master's program to make a marked change in their skillsets. Also, it is worth exploring whether a specific course is needed or whether a full academic program makes sense – which is a large commitment of time for the individual

and money and support for the organization. For example, if you and your systems engineer agree that they should get more proficient at architecture, is there a course on architecture at a university which may be more suitable than a full degree program?

The goal here is to have individuals leave a career planning session with not only a target of where they plan to grow, but a roadmap for how to get there - the name of a potential mentor, signed up for a training program, with a potential rotational assignment, etc. (See Section 5.4 for additional discussion on career paths.)

5.3.3 Building Archetypal Profiles

Another way that organizations can use proficiency profiles in growing their workforce is to create archetypes or expected profiles for specific positions or points in a career path. These, then, become draft **target proficiency profiles** as described above. They provide a reference for individuals that lay out the expectations of the organization and, paired with their validated current proficiency profile, will enable them to begin planning, realistically, their goals and career paths in the near term.

At ARDEC-SED, the Helix team worked with the management team to develop a set of "expected" profiles for several positions. The Helix team led the managers through a series of discussions around what the critical skills were for each position and how good an individual needed to be to be effective in that position. The term used in these discussions as "minimal proficiency to be effective" – meaning that this was the threshold managers believed an individual needed to do the job well. The team then worked with individuals in those positions, or who had recently left those positions, and helped them to assess their current (or recent past) proficiencies. The team then compared these proficiency profiles with the expected profile created by the management team and provided analysis on the discrepancies and alignments to the management team. With this data, the management team was able to determine whether or not to change their stated expectations.

MITRE has taken a different approach to this. For several key positions, MITRE asked acknowledged experts to create their own proficiency self-assessments, which were then validated in discussions with the team leading the effort. These "example" profiles then provide a basis for individuals interested in growing into those positions.

The above are two good examples of how this can be done in practice. There are a few points that the Helix team learned from working with these organizations that are useful to note:

- **Try not to ask for a superhero.** It is a common and very human thing to answer the question, "How good do you want an employee to be?" with the answer "the best". However, by definition, it is not possible for every single individual to be the best at everything. In one organization the Helix team worked with, when defining an expected

profile for one position, the team was told that the individual needed to be an "8" – on a 10-point scale, this would equate to a "4/Advanced" on the revised 5-point scale – in every competency area. While it is possible for a select few people to be "advanced" or "expert" in all areas, realistically, it is not possible for everyone to share this profile.

In fact, some individuals the Helix team worked with found these "superhero" profiles to be discouraging. Their rationale was that if the organization truly expected them to be expert in everything, then there was no way they would be able to fulfill those expectations. For very junior systems engineers, some felt that it would take 10-15 years to get to that level; as they all wished to provide value and be useful to their organizations earlier than that. The problem is not that they were not providing value – in fact, in their positions and the roles they played, many were – but that unrealistic expectations make them believe that their contributions could not be valued by the organization.

Does this mean that an organization should lower its standards and expectations? Of course not. But it is important to ensure that examples provided are actually attainable and not just by the "top 5%" talent because, by definition, most of the workforce will not fall into the 5%.

One thing to keep in mind is that systems engineers do not work in isolation. In some organizations, discussions about expectations led to the realization that the "minimum" was what was needed from a team of individuals. For example, there may be a chief systems architect, but a small team of systems architects who support that person. Instead of expecting that all individuals have this "minimum" set of requirements, it is possible that instead a team can collectively meet these minimums. Figure 13 shows an example of this:

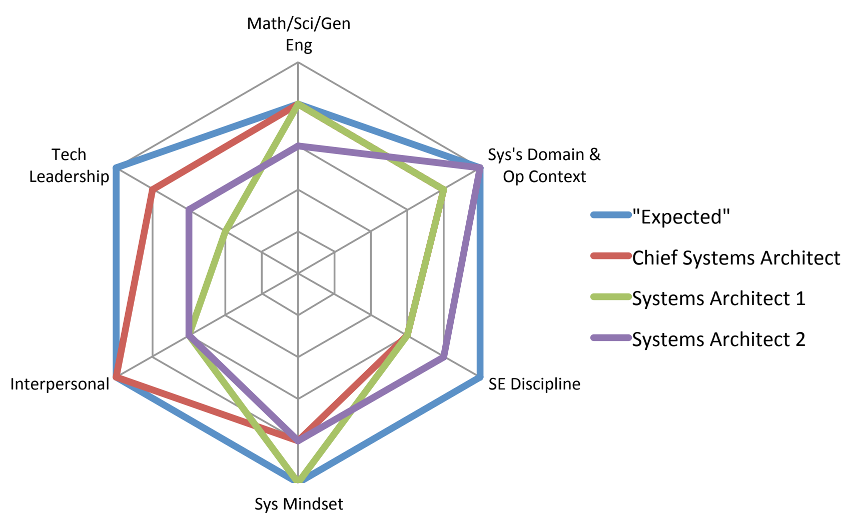


Figure 13. Example of team profiles compared to an "expected" profile.

In Figure 13, the expectation for proficiency for a systems architect is shown as quite high in all areas, which would be difficult for any individual to achieve. But if within that organization systems architecture is actually created via a team, then understanding how the team fits on the spectrum may be helpful. In this example, the team profile fills the expectations more fully than any of the individuals' profiles. Not that even with this team perspective, it appears that there is a gap in Technical Leadership and Systems Engineering Discipline. This could represent potential areas of growth within the team – perhaps with specific individuals targeting specific areas of growth – or could represent an example of where the expectations are not quite aligned with the proficiencies that are truly required. In either case, having the data to compare these is a critical step in helping the organization align required knowledge, skills, abilities, behaviors, and cognitions with existing abilities.*

- **Collect data to determine how aligned the archetypes are with current organizational realities.** Again, this does not mean that an organization can not set a high standard for a position but that the expectations need to have some alignment with realities.

  For example, imagine the following scenario: an organization creates an example profile for their "systems analyst" position, in which the expectation was that a *minimum* proficiency of "4" or "Advanced" was required in all proficiency areas. All of the individuals who currently in that position create **current proficiency profiles**, which are validated with their supervisors. Their self-assessments show that they range from an average of 2.5 to 4 in all proficiency areas, as illustrated in Figure 14.

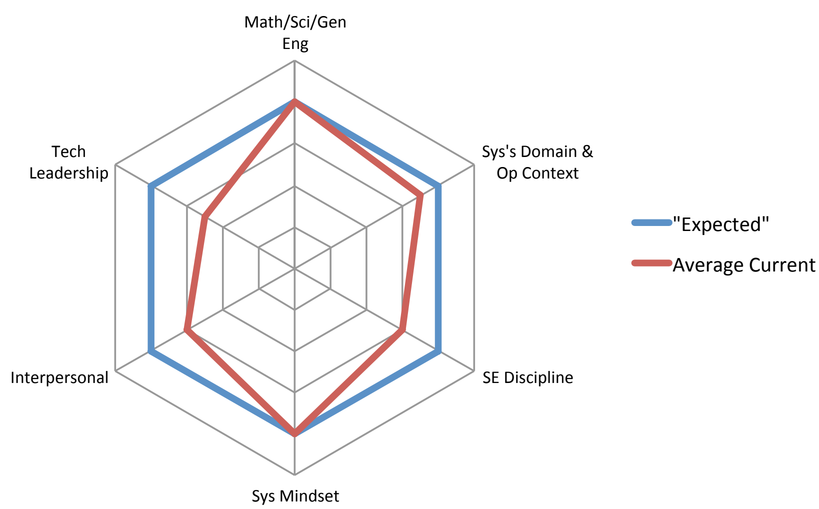


Figure 14. Example result of data collection against an archetypal profile.

* Note: It is also possible that there is some synergy between the individuals that would raise the "collective" profile of the team. This is an area the Helix team hopes to investigate further in future.

If used improperly, the results in Figure 14 might indicate that all individuals currently in the system analyst position fall below the "minimum" standard and could not possibly be effective. However, what is more likely is that management expectations and reality do not align. In fact, the Helix team saw this phenomenon at several organizations. With this data, the management team can now re-evaluate their example profile.

Does this mean that an organization can not set a higher standard than currently available in their workforce? Not at all. However, indicating to employees that they do not meet expectations and providing no further input would be disastrous. Instead, in such an instance, the management team should:

- Re-assess the example profile and make adjustments as appropriate. This could include creating multiple profiles. For example in the example above, perhaps there is a "minimum" profile, which is not a "4" or "Advanced" in all areas, and an "expert" profile, which shows the highest proficiency profiles expected in an area.
- Clearly communicate with the individuals in the position what the expectations are when they create their proficiency profiles, such as how the data will be used.
- If the "expected" profile remains the same, it would be critical to help individuals who do not meet that profile to create a plan for growth so that they can begin to close the gap between their current and the "expected" profile.

- **Do not overuse archetypal profiles or apply them too rigidly.** This is related to the point on expectations above. Having clear goals and targets can be very useful if they are employed in the right way. Giving an individual an "expected" profile with no additional information, however, can lead to discouragement. As discussed above, this can be counter productive. It is important to be clear about what the examples or archetypes really mean. For example, is this a true minimum for a position? If so, and especially if the profile falls into the "superhero" pitfall, some people may never plan on trying to attain that position.

No matter what techniques ore approaches an organization chooses to use, a common pattern seen in the Helix team's work with multiple organizations is that clear communication is critical if these example or archetypal profiles are going to be used successfully in an organization.

5.4 Utilizing Systems Engineering Roles

Atlas provides a list of 15 systems engineering "role" – specific sets of related systems engineering activities. These roles were founded on Sheard's "Twelve Systems Engineering Roles" (1996) and modified, expanded, and reorganized based on the Helix dataset. The roles are detailed in *Atlas 1.1*, but Table 7 briefly defines each role. For additional discussion on the roles, how they were developed, and how they are organized, see *Atlas* 1.1. For an

understanding of how the roles impact career paths, please see the *Atlas Career Path Guidebook*.

Table 7. Fifteen Systems Engineering Roles

#	Role Name	Role Description
1	Concept Creator	Individual who holistically explores the problem or opportunity space and develops the overarching vision for a system(s) that can address this space.
2	Requirements Owner	Individual who is responsible for translating customer requirements to system or sub-system requirements; or for developing the *functional* architecture.
3	System Architect	Individual who owns or is responsible for the architecture of the system.
4	System Integrator	Individual who provides a holistic perspective of the system; this may be the 'technical conscience' or 'seeker of issues that fall in the cracks' – particularly, someone who is concerned with interfaces.
5	System Analyst	Individual who provides modeling or analysis support to system development activities, and helps to ensure that the system as designed meets he specification.
6	Detailed Designer	Individual who provides technical designs that match the system architecture; an individual contributor in any engineering discipline who provides part of the design for the overall system. This is an addition based on the Helix data. While systems engineers do not always get involved with detailed design, in smaller organizations or on smaller projects it is more common.
7	V&V Engineer	Individual who plans, conducts, or oversees verification and validation activities such as testing, demonstration, and simulation.
8	Support Engineer	Individual who performs the 'back end' of the systems lifecycle, who may operate the system, provide support during operation, provide guidance on maintenance, or help with disposal.
9	Systems Engineering Champion	Individual who promotes the value of systems engineering to individuals outside of the SE community – to project managers, other engineers, or management. This may happen at the strategic level or could involve looking for areas where systems activities can provide a direct or immediate benefit on existing projects.
10	Process Engineer	Individual who defines and maintains the systems engineering processes as a whole and who also likely has direct ties into the business. This individual provides critical guidance on how systems engineering should be conducted within an organization context.
11	Customer Interface	Individual who coordinates with the customer, particularly for ensuring that the customer understands critical technical detail and that a customer's desires are, in turn, communicated to the technical team.
12	Technical Manager	Individual who controls cost, schedule, and resources for the *technical* aspects of a system; often someone who works in coordination with an overall project or program manager.

13	Information Manager	Individual who is responsible for the flow of information during system development activities. This includes the systems management activities of configuration management, data management, or metrics.
14	Coordinator	Individual who brings together and brings to agreement a broad set of individuals or groups who help to resolve systems related issues. This is a critical aspect of the management of teams.
15	Instructor/Teacher	Individual who provides or oversees critical instruction on the systems engineering discipline, practices, processes, etc. While any discipline could conceivably have an instructor role, this denotes a focus on systems and is a critical component in the development of an effective systems engineering workforce.

Note: In some organizations, the term "role" is used to define what is in *Atlas* referred to as a position: a specific job or title. This is not a problem, but particularly if you are using the roles within an organization that uses this terminology, it will be important to clarify. For example, in one organization that uses "role" to mean "job title", they call the *Atlas* roles, "activities".

5.4.1 Using Roles to Clarify the Value of Systems Engineers

Section 4.1 provides insight on clarifying the value that systems engineers and systems engineering are expected to provide within an organization. Another way in which organizations can help to clarify its expectations of value is to clearly define the systems engineers roles within the organization. Start with the roles identified in Table 5, organizations should review the roles and update them to reflect the organizational context. For example, in most government systems engineering groups that participated in Helix, the role of "concept creator" was uncommon. Individuals explained that given the DoD acquisition process, the higher level concepts were usually created before the systems engineers were engaged. This is not necessarily "wrong", but provides an opportunity for reflection about whether or not systems engineers *should* be engaged at this stage.

Likewise, there may be additional duties that a systems engineer performs in a specific organization. For example, in some small organizations, it is common for systems engineers to also perform program management duties. In the Helix dataset, this is reflected as "role that systems engineers often perform", but not a "systems engineering role". However, within your organization, this may be an expected part of value that systems engineers provide. In some organizations, systems engineers work closely with marketing department to ensure that what is communicated to the public accurately reflects the capabilities of the company's offerings. This, too, could be added as a systems engineering role.

Once an organization has created a set of standard roles for systems engineers, this becomes a tool for helping to clarify the values that systems engineers provide. If an organization states,

for example, that "Systems Integrator" is a systems engineering role that is critical in the organization, that helps to reinforce that systems engineers provide value to projects by ensuring that issues that could arise as components and subsystems are brought together are identified and dealt with earlier, helping to improve the overall performance of the program. This aligns nicely with the Enabling Value, "Systems engineers provide the big picture perspective, which is critical for understanding the system holistically and enabling system-level technical decisions, versus decisions made at the component or sub-system level." Whatever values are selected, they provide clear examples of how systems engineers are expected to contribute to products and programs.

5.4.2 Using Roles to Clarify the Positions of Systems Engineers

As seen in the Helix dataset, it was common that a systems engineer play more than one role in any given position. (See the *Career Path Guidebook* for additional details.) Several organizations shared with the Helix team – as did their systems engineers, program mangers, and classic engineers – that one of the frustrations commonly seen was the use (or misuse) of systems engineering titles. Program managers at several organizations, for example, stated, "When I get a systems engineer on my project, I don't know what I'm getting. Am I getting someone who will help the team work better together, understand the requirements, and help me work with the customer? Or am I getting someone who just graduated? There is no way to know."

Using the systems engineering roles to clarify positions may help to alleviate some of these issues. For example, the Helix team examined the first "chief systems engineer" role played by all the chief systems engineers in the sample. The results are shown in Figure 15.

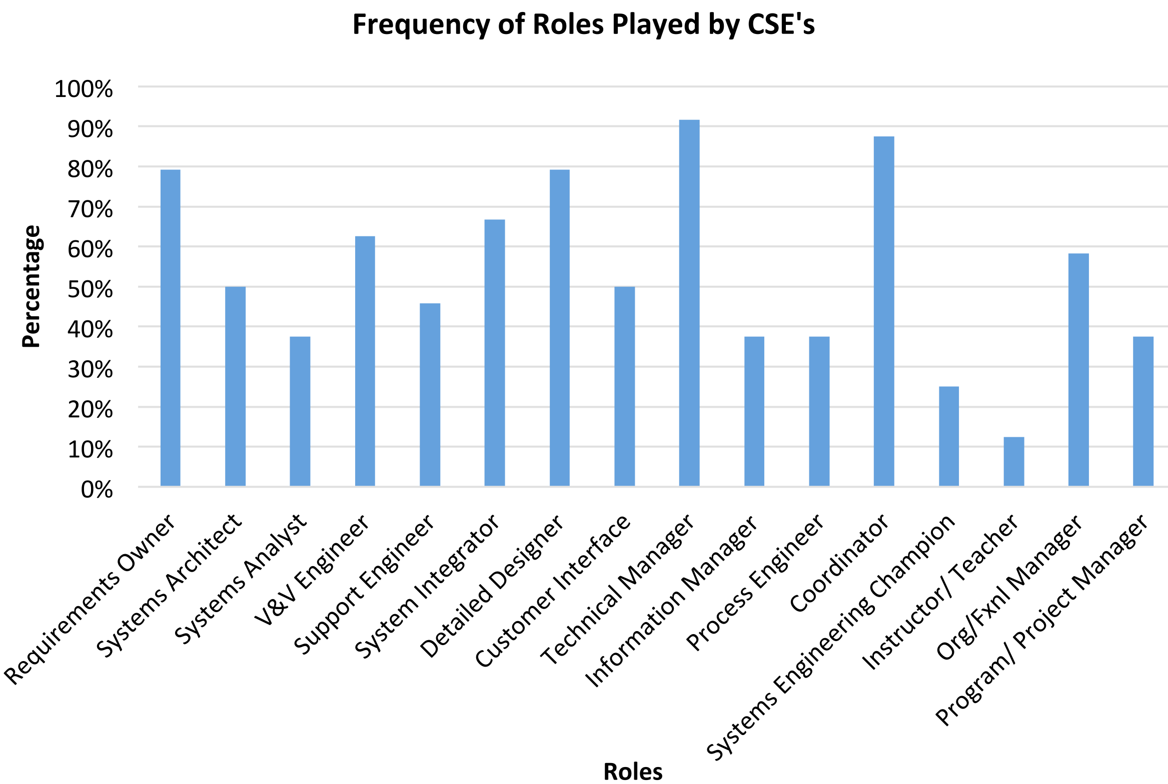


Figure 15. Roles played during initial chief systems engineering positions.

Using the types of patterns outlined in the *Career Path Guidebook* and the internal patterns within your systems engineering organization, it is possible to build common patterns that link to specific positions. For example, using the information in Figure 15, an organization may define a chief systems engineering (CSE) position using the roles illustrated in Figure 16.

Position: Chief Systems Engineer (CSE)	Key Roles
Description: *Individual granted formal responsibility to oversee and shepherd the technical planning, decision making, and execution for a program. The CSE will maintain a consistent vision for a system, often coordinating with many other engineers who have smaller scopes of responsibility as well as with the Program Manager.*	*All CSEs are expected to perform in the following roles*: • Technical Manager • Coordinator • Customer Interface • System Integrator • System Architect

Figure 16. Example description of CSE position using roles.

In Figure 16, a chief systems engineer will guide the program, manage technical decisions, help improve interfaces not only within the system but among the teams working on the system, and support or develop the architecture for the system. The CSE would not be expected to perform roles not described; for Figure 16, CSEs they would not likely be V&V Engineers or Support Engineers. (Though they would work with these individuals in their role as coordinator). While CSE may be a well-understood position, using a standard and consistent set of roles clearly sets expectations for the skills provided by individuals in each position. One could imagine that if all systems engineering positions are defined in this way, it would create a clearer and more consistent picture of the activities systems engineers are expected to perform. Paired with expectations around proficiency, the clarity around a position increases, as illustrated in Figure 17. Systems engineers would have clearer expectations of what it means to perform in a position. Program and project managers would better know what to ask for when developing their teams.

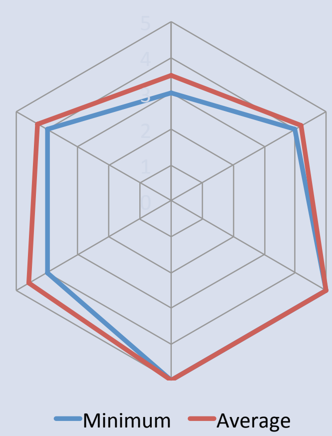
Position: Chief Systems Engineer (CSE)	Key Roles	Proficiency
Description: *Individual granted formal responsibility to oversee and shepherd the technical planning, decision making, and execution for a program. The CSE will maintain a consistent vision for a system, often coordinating with many other engineers who have smaller scopes of responsibility as well as with the Program Manager.*	*All CSEs are expected to perform in the following roles*: • Technical Manager • Coordinator • Customer Interface • System Integrator • System Architect	

Figure 17. Position description showing roles and proficiency.

This type of activity also provides an opportunity to identify any gaps. For example, if an organization creates its tailored list of systems engineering roles, then maps these roles across all systems engineering positions, the organization can then review whether all of the roles are clearly covered. If a role is important but not part of a position, this is a chance for the organization to add this explicitly – or determine whether the role is actually critical. Likewise, duplicates where the same role appears across multiple positions indicate an area where it would be helpful to clarify the scope of the role within positions. All of these activities give opportunities to minimize duplicate effort while streamlining and improving integration of common activities. And, again, provide an excellent tool to help non-systems engineers understand who systems engineers are and the activities they can perform on a project.

5.5 Utilizing Career Paths – Understanding the Forces that Grow Systems Engineers

The career path of *Atlas* is the characterization of the Forces over time: Experiences, Mentoring, and Education and Training. The *Career Path Guidebook* provides data on common patterns of career paths seen in the Helix sample, which may be very useful to organizations that are trying to create or update their career paths for systems engineers. The focus here is on how career paths may be useful for an organization. Note that while the term "career path" is used throughout this section, this does not mean that there is only one way to grow as a systems engineer or than an organization will have only one approach for developing its systems engineers. More likely, an organization will have a set of "career paths" or a framework of career guidance. However, for simplicity of language, the Helix team uses the term "career path".

One of the organizations that worked with the Helix team has a very clear career path for systems engineering – expected stages, a standard set of diverse experiences, areas of potential specialization, and even a process by which individuals in the organization become "official" systems engineers (and a process to get there). This is a very mature approach for a organization which views systems engineering as one of its core capabilities. It is not the only approach that works, but does have some advantages. First, by defining a clear career path analogous to those for electrical, mechanical, or software engineers, it puts systems engineering as a discipline on equal footing with these classic engineering disciplines. It also helps individuals understand where they are in the career path and where they can expect to grow. In this organization, systems engineers were able to envision a clear future for themselves at this organization.

Though more than one organization in the Helix dataset provided career guidance, for most organizations in the Helix sample, this type of clear and distinct career path did not exist. When the Helix team asked about career paths, the results were varied, ranging from an "organizational understanding about what works" that was not documented to statements that the guidance differed greatly depending on to whom you spoke, to outright laughter. Important for any organization that hopes to grow and mature its workforce, however, is that fact that in all of these organizations, systems engineers expressed a strong interest in having clearer guidance on their careers and clear paths or methods to grow and many were frustrated by the this.

Developing a clear career path for systems engineers gives the organization a few advantages:

- **It further supports the organization's view of the value systems engineers provide.** By creating a clear and distinct career path for systems engineers, it puts them on equal footing with many other disciplines that have established career paths. It signals to the systems engineers themselves and to their peers that it is a critical discipline for the organization. It also is a clear indicator that the systems engineers themselves are valuable enough to the organization that this sort of time and effort should be applied.

- **It reduces dependence on institutional memory.** Many of the systems engineers that participated in Helix said that they got career guidance from their manager or mentor or perhaps the "one person everyone knows that always can help you figure out what should be next". When the team asked whether this guidance or the context of the guidance was actually of use, participants explained that when the guidance came from someone who had seen many systems engineers over the years and "just had a sense for what worked". These individuals form a valuable resource for the organization. The problem arises when these individual leave the organization and this intuitional memory is lost. By collecting the input from these individuals and using it to construct a career path, the organization protects that knowledge and experience.

- **It may help with retention of systems engineers.** As stated above, many systems engineers who participated in Helix cited frustration with the lack of clear guidance they were able to access for their personal growth. Perhaps even more telling, many systems engineering managers in the sample stated that they could identify more than one instance of a systems engineer leaving the organization because they could not understand how they might grow and develop. By creating clear career paths, it helps enthusiastic systems engineers visualize how they might improve. Paired with clear roles and example positions, a systems engineer can understand the variety of positions he may be able to play and will have a basis for more intentionally driving his career path.

5.6 Critical Factors in Organizational Initiatives

Organizational initiatives are the methods organizations develop in an attempt to grow their systems engineering workforce, generally through applying one of the three Forces (experiences, mentoring, or education and training). Common examples include training courses, rotational programs, apprenticeships, mentor programs, and graduate cohorts.

When individuals discussed successes and failures with organizational initiatives, there were four factors that stood out as critical to the success of any initiative:

- **Establishing the right initiative:** Like in any good systems engineering development, identifying the requirements and addressing them appropriately while establishing the initiative is a necessary first step.
- **Spreading the word:** Any organizational initiatives will be ineffective when an intended beneficiary is unaware that such an initiative exists within the organization. Organizations must take an effort to let its employees know about their eligibility and existence of any organizational initiatives, and enable them to benefit from them.
- **Periodical evaluation of the initiative:** Due to the dynamic nature of the organizational environment, it is important to critically evaluate any initiative periodically to identify modifications that need to be made to the initiative.
- **Commitment from leadership:** Even if many relevant and effective initiatives were

available, commitment from the organizational and immediate leadership is essential for an employee to benefit from an initiative.

These principles are highlighted throughout the sections above, but are worth highlighting separately so that organizations can keep them in mind when deciding whether to develop new initiatives.

6: CONCLUSIONS: BRINGING IT ALL TOGETHER

Atlas is intended to provide systems engineers and organizations that employ systems engineers with information on what makes systems engineers effective. This Implementation Guide is intended to help take that theory and put it into practice.

Individuals can use the information to understand and assess their own knowledge, skills, and abilities; understand and analyze their own career paths, and link the two to develop plans and paths for growth.

Organizations will be able to:

- Clear and consistent definitions for systems engineering and the value that systems engineer provide;
- Clear and consistent expectations on the roles systems engineers play within the organization;
- Clear and consistent expectations on the knowledge, skills, abilities, behaviors, and cognitions of systems engineers;
- Career path recommendations and supporting initiatives that enable the growth and development of the systems engineering workforce.

If all of these are brought together, an organization may need to be able to provide guidance such as illustrated in Figure 18. This example shows a potential "career path" for an organization over time – in this case a series of positions expected to enable a person to grow. These positions include the highest-level systems engineering positions in the organization. Each position provides clear guidance on the expectations in terms of both the systems engineering roles to be played and proficiencies associated with the position. In this case, both the "anticipated minimum" proficiencies (blue line) and the current average proficiencies of individuals in this position (red line) are included. Finally, Figure 18 provides example career paths from individuals who currently serve in these positions. All of this information can be utilized by individuals within the organization to guide their own careers and by managers and leaders to help grow the workforce.

Figure 18 is notional and the specifics illustrated are far less important than the idea that an organization can provide clear, consistent guidance based on rigorous assessments and data collection that will enable them to grow their workforce.

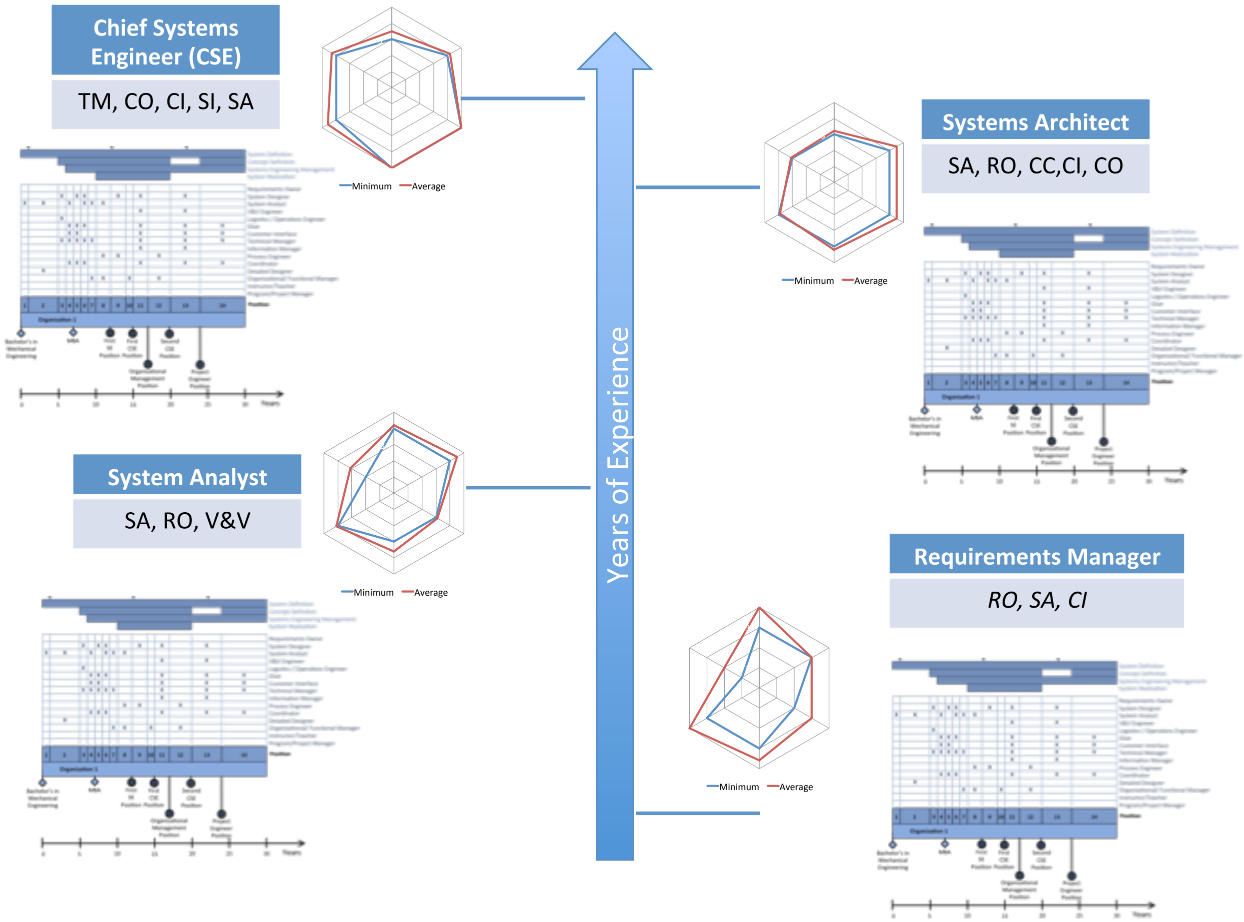


Figure 18. An example career path, with positions, roles, and proficiencies.

By using *Atlas*, the Helix team believes that organizations can better provide their systems engineers with the information and tools needed to grow and develop into an effective workforce.

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Appendix A: Paper-Based Tools for Assessing Proficiency

Proficiency defines the knowledge, skills, abilities, behaviors, patterns of thinking, and abilities that are critical to the effectiveness of systems engineers. The *Atlas* proficiency model consists of six difference proficiency areas:

- **Math/Science/General Engineering**: Foundational concepts from mathematics, physical sciences, and general engineering;
- **System's Domain & Operational Context**: Relevant domains, disciplines, and technologies for a given system and its operation;
- **Systems Engineering Discipline**: Foundation of systems science and systems engineering knowledge;
- **Systems Engineering Mindset**: Skills, behaviors, and cognition associated with being a systems engineer;
- **Interpersonal Skills**: Skills and behaviors associated with the ability to work effectively in a team environment and to coordinate across the problem domain and solution domain; and
- **Technical Leadership**: Skills and behaviors associated with the ability to guide a diverse team of experts toward a specific technical goal.

Each of these areas contains several categories, or groupings of related knowledge, skills, abilities, behaviors, or cognitions, as illustrated in Table 1.

Self-Assessment

In order to perform a self-assessment, individuals are asked to review the definitions of the proficiency areas above and the categories in Table 1. Additional detail can be found in the full report on *Atlas 1.0*, SERC-2016-TR-118, found at the Helix webpage (http://www.sercuarc.org/projects/helix/). Then use the template to generate a "0 to 10" initial assessment of your current proficiency in each Area, with "0" meaning you have no skill in the area and 10 meaning your skills are the top within your experiences. Consider the following guidelines:

- For each Proficiency Area, think about proficiency across *all categories*, not just one. For example, if you are a "10" in a single category, but a "5" in all others, you would not be a "10" for the entire Area.
- For each Area, think about what is most critical for your current position. This may not change your assessment, but may mean that a lower number not an issue.
- Consider your past experiences in the Area, any training or education that might be relevant, and where you might have received guidance from a mentor or leader. These things together will have shaped your proficiency, and thinking about them may help you to assess yourself more realistically.
- You know your strengths and areas for growth – be honest in your responses.

A proficiency rubric for further guidance can be found on page 78.

Once you have completed your initial assessment for your *current* proficiency, you can choose to retroactively assess what your proficiency was at different points in your career. For example, when you completed your undergraduate education or joined your current

organization. This may help you to better reflect on changes over time. If you do this, revisit your current proficiency assessment afterwards and determine whether any adjustments are required.

As discussed in the *Implementation Guide*, you should first review and tailor the rubric as appropriate for your position.

ATLAS SELF-ASSESSMENT RUBRIC

The following is the self-assessment rubric provided by *Atlas*. As with the proficiency model itself, you should review and tailor this as appropriate.

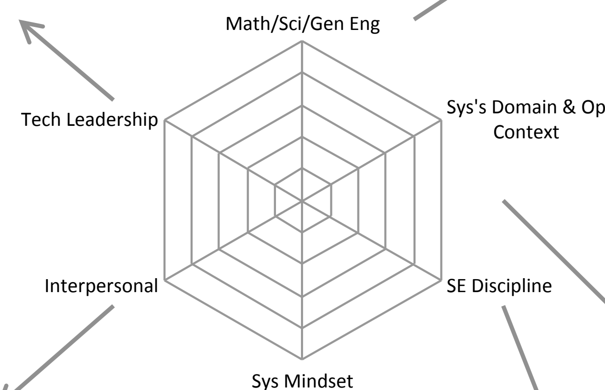
#	Level	Level Description
1	**Fundamental Awareness**	Individual has common knowledge or an understanding of basic techniques and concepts. Focus is on learning rather than doing.
2	**Novice**	Individual has the level of experience gained in a classroom or as a trainee on-the-job. Individual can discuss terminology, concepts, principles, and issues related to this proficiency, and use the full range of reference and resource materials in this proficiency. Individual routinely need help performing tasks that rely on this proficiency.
3	**Intermediate**	Individual can successfully complete tasks relying on this proficiency. Help from an expert may be required from time to time, but the task is usually performed independently. The individual has applied this proficiency to situations occasionally while needing minimal guidance to perform it successfully. Individual understands and can discuss the application and implications of changes in tasks relying on the proficiency.
4	**Advanced**	Individual can perform the actions associated with this proficiency without assistance. The individual has consistently provided practical and relevant ideas and perspectives on ways to improve the proficiency and its application and can coach others on this proficiency by translating complex nuances related to it into easy to understand terms. Individual participates in senior level discussions regarding this proficiency and assists in the development of reference and resource materials in this proficiency.
5	**Expert**	Individual is known as an expert in this proficiency and provides guidance and troubleshooting and answers questions related to this proficiency and the roles where the proficiency is used. Focus is strategic. Individual have demonstrated consistent excellence in applying this proficiency across multiple projects and/or organizations. Individual can explain this proficiency to others in a commanding fashion, both inside and outside their organization.

ATLAS SELF-ASSESSMENT TOOL (PAPER BASED)

The following page provides the paper based self-assessment tool provided by *Atlas*.

Date or Position:

____



Building and Orchestrating a Diverse Team	
Balanced Decision Making & Rational Risk Taking	
Guiding Diverse Stakeholders	
Conflict Resolution & Barrier Breaking	
Business and PM Skills	
Establishing Technical Strategies	
Enabling Broad Portfolio-Level Outcomes	
Self-Assessment	

Natural Science Foundations	
Engineering Fundamentals	
Probability and Statistics	
Calculus and Analytical Geometry	
Computing Fundamentals	
Self-Assessment	

Principal and Relevant Systems	
Familiarity with System's Concept of Operations	
Relevant Domains	
Relevant Technologies	
Relevant Disciplines and Specialties	
System Characteristics	
Self-Assessment	

Communications	
Listening and Comprehension	
Working in a Team	
Influence, Persuasion, and Negotiation	
Building a Social Network	
Self-Assessment	

Big Picture Thinking	
Paradoxical Mindset	
Adaptability	
Abstraction	
Foresight and Vision	
Self-Assessment	

Lifecycle	
Systems Engineering Management	
SE Methods, Processes, and Tools	
Systems Engineering Trends	
Self-Assessment	

APPENDIX B: PAPER-BASED TOOLS FOR ASSESSING CAREER PATH

An individual's career path is the precise combination of experiences, mentoring, education, and training that an individual goes, particularly their characteristics, timing, and order. In order to complete a career assessment, an individual should work through the steps outlined here while filling out the career path template.

Experiences

The Helix team chose to use a **position** as the unit of measure for experiences; a position is established by the organization and defines the roles and responsibilities to be performed.
Based on both the literature and the Helix data itself, each position has several characteristics:

- **Relevance:** A 'relevant' position is one that enables a systems engineer to develop the proficiencies critical to systems engineering. Determine a starting point for relevant experiences; this will become the first position (P1) of the career path. Fill in the title and the year(s) for the position(s).
- **Organizations:** Fill out the name of the organization for each position. This will help to show any transition or variation between organizations.
- **Roles:** A role is a collection of related systems engineering activities. Roles were identified based on the activities consistently performed by systems engineers. There are 16 roles identified in *Atlas*, as described in Table 1, below. For each position, review your activities and responsibilities and write down *all* roles played during that position.
- **Lifecycle Phases:** Generic systems engineering lifecycle phases considered in *Atlas* are based on the lifecycle phases in the *Guide to the Systems Engineering Body of Knowledge (SEBoK*), as explained on page 5. (BKCASE Authors 2016) For each position, fill in the area(s) of the lifecycle you worked on.
- **Key Milestones.** Note any key changes in types of positions under key milestones. For example, first systems engineering role, first chief systems engineer role, first supervisory position, etc. would all be indicators of change or growth over career.

Education and Training

Note any educational milestones or key training milestones with the position/timeline in which they occurred. Education milestones may include the completion of a degree or participation in a course that was particularly relevant or impactful for your career. Key training is training that was particularly impactful or useful for your career. You do not need to include training that did not have an impact.

Other

Your organization may ask you to add other information, such as participation in professional societies, publications, etc. to your career path.

Role Name	Role Description
Roles Focused on the Systems Being Devleoped	
Concept Creator	Individual who holistically explores the problem or opportunity space and develops the overarching vision for a system(s) that can address this space. A major gap pointed out to the Helix team – particularly when working to implement the findings of Helix – has been that of the development of an overarching system vision. This is a critical first step in the systems lifecycle, and several organizations stated that they believed it needed to be separately called out. In addition, when looking to the future of what systems engineers need to do (e.g., INCOSE Vision 2025 (2015)), the focus on early engagement and setting the vision was deemed critical.
Requirements Owner	Individual who is responsible for translating customer requirements to system or sub-system requirements. This is updated from Atlas 1.0. Sheard (1996) also included the activities around functional architecture in this role. However, in working with the community, this has caused some confusion as to the differences between this role and that of "System Architect". The Helix team believes that grouping all architecture activities together will improve clarity on the roles.
System Architect	Individual who owns or is responsible for the architectures of the system; this including functional and physical architectures. This is updated from *Atlas* 1.0. This is an update of Sheard's "System Designer" role (1996). There was concern both at community events and during later interviews that nowhere in the presented framework did the critical role of systems engineers in architecture come out clearly. Some also argued that "Design" gave the impression that this role focuses specifically on the details of systems design over architecture.
System Integrator	Individual who provides a holistic perspective of the system; this may be the 'technical conscience' or 'seeker of issues that fall in the cracks' – particularly, someone who is concerned with interfaces. Likewise, there was concern over the word "Glue", which many expressed was not clearly descriptive enough.
System Analyst	Individual who provides modeling or analysis support to system development activities, and helps to ensure that the system as designed meets he specification. This is unchanged from Sheard's roles (1996).
Detailed Designer	Individual who provides technical designs that match the system architecture; an individual contributor in any engineering discipline who provides part of the design for the overall system. This is an addition based on the Helix data. While systems engineers do not always get involved with detailed design, in smaller organizations or on smaller projects it is more common. Likewise, systems engineers who had played this role explained that it was critical in developing their own technical and domain expertise as well as in understanding the design approaches of classic engineers.
V&V Engineer	Individual who plans, conducts, or oversees verification and validation activities such as testing, demonstration, and simulation. This is unchanged from Sheard's roles (1996).

Role Name	Role Description
Support Engineer	Individual who performs the 'back end' of the systems lifecycle, who may operate the system, provide support during operation, provide guidance on maintenance, or help with disposal. This was previously titled "Logistics and Operations Engineer" in Sheard (1996). However, in interviews and at community events, the Helix team received feedback that using this title gave the impression that this role was limited and did not encompass the full spectrum of systems engineers' activities at system deployment or post-deployment. Likewise, in several organizations, "logistics" and "operations" were seen as separate disciplines from systems engineering, which caused some contention in discussions. The renaming of this category is intended to address these issues.
Roles Focused on Process and Organization	
Systems Engineering Champion	Individual who promotes the value of systems engineering to individuals outside of the SE community – to project managers, other engineers, or management. This may happen at the strategic level or could involve looking for areas where systems activities can provide a direct or immediate benefit on existing projects. Sheard recommended that a role such as this, labeled in her work as "Systems Engineering Evangelist", be added in (2000).
Process Engineer	Individual who defines and maintains the systems engineering processes as a whole and who also likely has direct ties into the business. This individual provides critical guidance on how systems engineering should be conducted within an organization context. This is unchanged from Sheard's roles (1996).
Roles Focused on the Teams That Build Systems	
Customer Interface	Individual who coordinates with the customer, particularly for ensuring that the customer understands critical technical detail and that a customer's desires are, in turn, communicated to the technical team. This is unchanged from Sheard's roles (1996).
Technical Manager	Individual who controls cost, schedule, and resources for the *technical* aspects of a system; often someone who works in coordination with an overall project or program manager. This is unchanged from Sheard's roles (1996).
Information Manager	Individual who is responsible for the flow of information during system development activities. This includes the systems management activities of configuration management, data management, or metrics. This is unchanged from Sheard's roles (1996).
Coordinator	Individual who brings together and brings to agreement a broad set of individuals or groups who help to resolve systems related issues. This is a critical aspect of the management of teams. This is unchanged from Sheard's roles (1996).
Instructor/Teacher	Individual who provides or oversees critical instruction on the systems engineering discipline, practices, processes, etc. This can include the development or delivery of training curriculum as well as academic instruction

Role Name	Role Description
	of formal university courses related to systems engineering. While any discipline could conceivably have an instructor role, this denotes a focus on systems and is a critical component in the development of an effective systems engineering workforce. This is an addition to the Sheard roles (1996 and 2000).

Systems Engineering Lifecycle

- **Concept Definition** - A set of core technical activities of SE in which the problem space and the needs of the stakeholders are closely examined. This consists of analysis of the problem space, business or mission analysis, and the definition of stakeholder needs for required services within it.
- **System Definition** - A set of core technical activities of SE, including the activities that are completed primarily in the front-end portion of the system design. This consists of the definition of system requirements, the design of one or more logical and physical architectures, and analysis and selection between possible solution options.
- **System Realization** - The activities required to build a system, integrate disparate system elements, and ensure that a system both meets the needs of stakeholders and aligns with the requirements identified in the system definition stage. This includes integration, verification, and validation (IV&V).
- **System Deployment and Use** - A set of core technical activities of SE to ensure that the developed system is operationally acceptable and that the responsibility for the effective, efficient, and safe operations of the system is transferred to the owner. Considerations for deployment and use must be included throughout the system life cycle. Activities within this stage include deployment, operation, maintenance, and logistics.
- **Product and Service Life Management** - Deals with the overall life cycle planning and support of a system. The life of a product or service spans a considerably longer period of time than the time required to design and develop the system. This stage includes service life extension, updates, upgrades, and modernization, and disposal and retirement. The organizations in the current sample are primarily concentrated on new development, so this is a very under-represented aspect of the life cycle.
- In addition to these life cycle phases, the SEBoK includes orthogonal activities of systems engineers, **Systems Engineering Management**, defined as managing the resources and assets allocated to perform SE activities. Activities include planning, assessment and control, risk management, measurement, decision management, configuration management, information management, and quality management. These activities can occur at any point in the systems engineering lifecycle.

Career Path Self-Assessment Tool

Date: ____________

Concept Definition										
System Definition										
System Realization										
System Deployment and Use										
Product and Service Life Management										
Systems Engineering Management										
Role(s) Performed										
Domain(s)										
System Characteristics										
Position										
Organization(s)										
Dates										
Milestones (Key positions, education, or training)										